Fishery Data Series No. 16-36

Feasibility of Estimating Salmon Abundance in the Tanana River Using Sonar, 2012–2014

by

Naomi B. Brodersen

Bruce C. McIntosh

and

Carl T. Pfisterer

September 2016

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by
Naomi B. Brodersen, Bruce C. McIntosh, and Carl T. Pfisterer
Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

September 2016

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Naomi B. Brodersen, Bruce C. McIntosh, and Carl T. Pfisterer
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Road, Fairbanks, AK 99701, USA

This document should be cited as follows:
Brodersen, N. B., B. C. McIntosh, and C. T. Pfisterer. 2016. Feasibility of estimating salmon abundance in the Tanana River using sonar, 2012–2014. Alaska Department of Fish and Game, Fishery Data Series No. 16-36, Anchorage.

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ABSTRACT

A study was conducted from 2012 to 2014 to assess the feasibility of using sonar, in combination with gillnetting and a fish wheel, to estimate salmon abundance in the Tanana River. Eight sites between Cosna Bluff and the confluence of the Kantishna and Tanana rivers were surveyed, bottom profiles were analyzed for suitability of sonar operation, and a site near Manley Hot Springs was selected. Split-beam sonar was operated on the left bank, and imaging sonar on the right bank. Drift and set gillnets were used to apportion the left-bank sonar estimates, and drift gillnets and a fish wheel were used to apportion the right-bank sonar estimates. Both sonar and test fishing methods were modified and assessed for effectiveness throughout both seasons. The sonars were found to provide effective coverage with 95% of fish passing within 80 m of the transducer on the left bank, and within 16 m on the right bank. The drift gillnets and fish wheel proved to be effective fishing methods, although refinement of these methods should be a goal in future seasons. Based on the information obtained, estimating salmon abundance in the Tanana River using sonar, with drift gillnets and a fish wheel used for species apportionment, is feasible.

Key words: Pacific salmon, *Oncorhynchus* spp., Chinook *O. tshawytscha*, chum *O. keta*, coho *O. kisutch*, hydroacoustics, sonar, split-beam, ARIS, fish wheel, gillnet, apportionment, Tanana River, Yukon River, Alaska

INTRODUCTION

The Tanana River, as one of the main producers of Chinook salmon *Oncorhynchus tshawytscha*, fall chum salmon *O. keta*, and coho salmon *O. kisutch* in the U.S. portion of the Yukon River drainage (Eiler et al. 2004; Cleary and Hamazaki 2008; JTC 2015), has had an irregular history of projects that could produce timely estimates of salmon abundance (JTC 2015). Several projects aimed at estimating relative salmon abundance in the Tanana River have been operated since the mid-1980s but have been discontinued due to loss of funding. These include test fishery wheels operated near Manley Hot Springs from 1984 to 1985 and 1988 to 1994, near Nenana from 1988 to 2011, and near the mouth of the Tanana River from 1994 to 2012 (Borba 2007; Fliris and Daum 2003). Radiotelemetry projects aimed at estimating fall chum salmon spawning abundance were operated on the Tanana River in 1989 and from 2007 to 2008, and a fall chum salmon abundance mark–recapture project was operated from 1995 to 2007 (Barton 1992; Cleary and Hamazaki 2008).

Several tributaries of the Tanana River provide spawning habitat for salmon. Historically productive tributaries for Chinook and summer chum salmon include the Chena, Salcha, and Goodpaster rivers; those for fall chum salmon include the Toklat River (a tributary of the Kantishna River), Delta River, and sloughs in the mainstem Tanana River; and the primary producer for coho salmon has been the Delta Clearwater River (JTC 2015). Due to the substantial fall chum salmon returns to the Kantishna River drainage, it was important to locate a sonar site downstream of this tributary, in order to include these fish in the overall Tanana River estimate.

Chinook salmon typically begin to enter the Tanana River in mid- to late June (Fliris and Daum 2003). Chum salmon return to the Yukon River in genetically divergent summer and fall runs (Crane et al. 2001); summer chum salmon typically enter the Tanana River in late June, fall chum salmon in early to mid-August, and coho salmon in mid-August (Fliris and Daum 2003). Chinook, summer chum, fall chum, and coho salmon are captured in subsistence, personal use, commercial, and sport fisheries along the Tanana River and are critical to the way of life and economy of people in many communities.

The Yukon River drainage is divided into 6 management districts, of which the Tanana River is District 6 (Figure 1). From 2009 to 2013, District 6 accounted for approximately 3.4% of the

Chinook salmon, 1.4% of the summer chum salmon, 17.2% of the fall chum salmon, and 46.8% of the coho salmon subsistence and personal use harvest in the Alaska portion of the Yukon River drainage. Currently, the Alaska Department of Fish and Game (ADF&G) operates a counting tower (with a dual-frequency identification sonar [DIDSON[1]] backup for high water events) on the Chena River to monitor Chinook and summer chum salmon escapement (Savereide and Huang 2014) and performs boat surveys in the Delta Clearwater River to estimate coho salmon escapement (Savereide and Huang 2014). The Bering Sea Fisherman's Association (BSFA) operates a counting tower on the Salcha River, and the Tanana Chiefs Corporation (TCC) operates a counting tower on the Goodpaster River, both aimed at estimating Chinook and summer chum salmon escapement (Savereide and Huang 2014). In addition, ADF&G performs aerial and foot surveys in selected areas of the upper Tanana River in late fall to estimate Chinook, chum, and coho salmon escapement. Although these projects provide important escapement information for selected tributaries, there are no projects attempting to estimate total abundance in the Tanana River for any salmon species. Genetic samples taken from the Pilot Station sonar test fishery are used to estimate the proportion of Yukon River Chinook and chum salmon that belong to Tanana River stocks; however, there is no way to accurately measure the harvest that takes place upstream from Pilot Station inseason. Because timely estimates of salmon abundance entering the Tanana River are unavailable for management, surpluses of these stocks have been forgone in most years because of uncertainty surrounding the strength of the runs. Commercial harvests could potentially be increased if salmon passage estimates were known.

The high turbidity and considerable width of the Tanana River make fish counting towers and weirs impractical for estimating fish passage. Sonar has been used successfully in several large, turbid rivers in Alaska to provide salmon abundance estimates (ADF&G 2015). In the U.S., ADF&G operates projects on the Yukon River near the villages of Pilot Station and Eagle, and on the Anvik River, and the U.S. Fish and Wildlife Service (USFWS) has a sonar project on the Chandalar River (Melegari 2015). The project near Pilot Station operates under similar conditions to those found on the Tanana River, and thus the Tanana River project was initially patterned after that project.

A sonar project was attempted on the mainstem Tanana River near the village of Manley Hot Springs in 1990, and it was thought the site had promise (LaFlamme 1990). This early trial only operated for a limited time that did not include peak passage for any salmon species. Drift gillnetting for species apportionment was possible on the right bank but was deemed unsafe on the left bank due to submerged trees. It is not known why the project was discontinued other than a lack of dedicated funding. The importance of managing overall Yukon River and Tanana-specific salmon runs and improvements in the technology over the last decade rekindled interest in using sonar to estimate salmon abundance in the Tanana River. Because 2 decades had elapsed since this earlier work had been performed, it was decided to start over and search for a new site because of potential changes to the river channel. In 2012, an initial investigation was conducted to identify potential sonar sites downstream of the Kantishna River. In 2013, from June 3 through September 23, a site near Manley Hot Springs was selected, a camp was constructed, and preliminary studies were conducted to assess the effectiveness of sonar and test fishing methods. In 2014, from June 26 through September 25, a nearly complete season of sonar data

[1] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

was collected for Chinook, summer chum, fall chum, and coho salmon runs, and test fishing methods were further evaluated and refined.

OBJECTIVES

The purpose of this project was to assess the feasibility of using sonar to estimate fish passage in the Tanana River and to assess the effectiveness of different test fishing methods to apportion the sonar counts by species. Primary objectives included the following:

1) Identify a location on the lower Tanana River with a substrate structure suitable for operating sonar on both banks.
2) Deploy split-beam and imaging sonars on both banks, determine optimal settings for fish detection, and assess effectiveness of fish detection.
3) Use a fish wheel, drift gillnets, and set gillnets to catch species detected by the sonar on both banks and compare the effectiveness of each method.
4) Estimate the daily and seasonal passage of Chinook, chum, and coho salmon, and compare those to estimates generated independently at other projects.

Secondary objectives included the following:

1) Collect biological data from all fish captured in the test fishery, including species, age (for Chinook salmon), sex, and length (ASL).
2) Collect daily climatic and hydrologic measurements representative of the study area.

METHODS

INITIAL INVESTIGATIONS

Eight sites on the Tanana River downstream of the Kantishna River were identified as having a single channel (Figure 2). In September and October 2012, at each of these sites, transects were performed with a skiff, and river bottom profile data were collected using a Humminbird 998C SI fathometer with GPS and a Lowrance LCX15MT fathometer with GPS. In addition, notes on substrate, general shape of the river, location of sandbars, river width, bank angle and stability, swiftness of current, presence of back eddies, presence of visible snags, vegetation, presence of potential campsites, and presence of clean water sources, were recorded. Of these 8 sites, 2 had nearly linear river bottom profiles on both banks (Figure 3), an important feature for reliable fish detection. They also met several of the other criteria for acceptable project sites, such as close proximity to a community, and high ground to build a field camp, a nearby water source, and features conducive to a test fishery. One was near Cosna Bluff, at approximate river mile 42 (km 68), and the other was downstream from the mouth of Hot Springs Slough, at approximate river mile 57 (km 92). Of the 111 total transects, 28 were performed at the Cosna Bluff site and 39 at the Hot Springs Slough site. The river bottom profiles from the Cosna Bluff site were slightly more linear than those at the Hot Springs Slough site, and the river was narrower (with an average width of 226 m across versus 291 m). However, at the Cosna Bluff site there was a flat shelf along the nearshore region of the left bank (when facing downstream), which would be less desirable for sonar deployment during times of high water. Project leaders decided it would be beneficial to perform more transects the following spring after breakup to assess river bottom stability at these 2 sites.

In early June 2013, another set of transects was performed, 15 at the site near Cosna Bluff and 18 at the site near Hot Springs Slough. The river bottoms at both of these sites appeared to be stable, and had not changed much since the previous fall. When the spring 2013 transects were performed, the water level was much higher than when the fall 2012 transects were performed, which is typical for the Tanana River. It became apparent that the steep bank and fast current on the right bank at the Cosna Bluff site could make sonar deployment difficult during times of high water. In addition, the close proximity of the Hot Springs Slough site to the town of Manley Hot Springs made it preferable for logistics and fuel consumption. From mid-June through early July, 2013, a field camp was constructed on the south bank of the Tanana River near the mouth of Hot Springs Slough.

STUDY SITE

The Tanana River flows northwesterly from the confluence of the Nabesna and Chisana rivers in eastern Alaska, to the Yukon River near the village of Tanana in Central Interior. It is one of the largest tributaries of the Yukon River, passing by the city of Fairbanks, as well as several smaller towns and villages. The basin covers an area of approximately 44,300 square miles, and the length spans a distance of approximately 1,060 km (Brabets et al. 2000). The Tanana River is highly dynamic, characterized by rapid erosion and deposition, braided channels, sandbars, and unstable cut banks. It is primarily a glacial-fed river, draining the north side of the Alaska Range, and has a high concentration of suspended sediment, with an estimated annual load of 38,000,000 tons at Nenana (Brabets et al. 2000) and an average flow of 44,600 cubic feet per second (Brabets et al. 2000).

The primary study site was a 0.5 mi stretch of the Tanana River near the mouth of Hot Springs Slough, at approximate river miles 57 (km 92) (Figure 4). At this location the river formed a single channel, with an approximate river width of 300 m. The substrate on the right bank was mostly rocky, with a slope of approximately 25°. The left bank had a much more gradual slope at approximately 6° and a silty substrate with numerous submerged trees embedded in the silt (snags). Because of the different substrates, the right bank bottom profiles were relatively stable compared to the left bank bottom profiles. The sonar transducers, left bank fishing zones, and right bank fish wheel were all located at the primary study site.

An additional drift gillnet fishing site was located approximately 2.9 km downstream from the primary study site on the right bank. This downstream fishing site was similar to the primary study site in that the river formed a single channel, the right bank substrate was rocky with a slope of approximately 25°, the left bank was silty, and there were several snags, primarily on the left bank. The main differences were that the river bottom profile was not linear, with the middle section of the river being mostly flat with some irregular dips and mounds, and overall, the river was wider with an approximate width of 400 m. In addition, the slope of the left bank was slightly steeper at approximately 8°.

At the primary study site, a lease was obtained from a private land owner to utilize the land on the left bank of the river, and a permit was obtained from Doyon, Ltd. to utilize the land on the right bank. A semi-permanent field camp was constructed on the left bank of the river, centered at 64°58.55′N, 150°49.36′W. A sonar tent was constructed approximately 240 m downstream, at 64°58.51′N, 150°49.65′W, and a portable wooden shed was constructed on the right bank at 64°58.68′N, 150°49.76′W, to house the right bank sonar equipment.

SONAR DATA ACQUISITION

Bottom Profiles

Bottom profile data were collected every 1 to 2 weeks throughout both the 2013 and 2014 seasons to monitor any changes in the shape of the river bottom, and ensure that the sonar was at an acceptable location for fish detection. River bottom profiles were generated by driving a skiff perpendicular to shoreline across the river from bank to bank or ‘transecting’ the river, while collecting depth and global position data using a Humminbird 998C SI fathometer with GPS. Transects were spaced approximately 25 to 50 m along a 400 m stretch of river. Data were transferred to a computer, plotted using Microsoft Excel, and examined to determine acceptable locations for the sonar—specifically, where the riverbank had a relatively linear, downward sloping bottom.

Equipment

Based on the profiles, substrate, and experience at other sonar sites, split-beam sonar, with its narrow beam and greater range, was deployed on the left bank. Imaging sonar (DIDSON and adaptive resolution imaging sonar [ARIS]) was best suited for the rocky substrate and shorter, steep profile of the right bank.

The left bank sonar equipment included the following:

1) A model 241-2 split-beam echosounder manufactured by Hydroacoustic Technology, Inc. (HTI), operated at 200 kHz, controlled by digital echo processor (DEP) software (version 05.00) on a laptop computer,
2) A 2.8° x 10° 200 kHz split-beam HTI transducer,
3) Three 250 ft HTI model 642-250 split-beam transducer cables,
4) Three 250 ft HTI model 652-250 rotator cables,
5) Two HTI model 662H single-axis rotators, 1 controlling pan, and 1 controlling tilt, and
6) An HTI model 660-2 remote rotator controller.

The echosounder and laptop computer were housed in the sonar tent on the left bank of the river. The transducer was connected to the rotators, which were mounted to a rectangular pod made of aluminum pipe (Figure 5). The echosounder, transducer, and transducer cables were calibrated by HTI prior to the field season (Urick 1983).

The right bank sonar equipment included the following:

1) An adaptive resolution imaging sonar (ARIS) Explorer 1200 model, manufactured by Sound Metrics, Corp., operated at 0.7 MHz, controlled by ARIScope software (version 2.5) on a laptop computer,
2) A Dual-frequency identification sonar (DIDSON) Long-Range (LR) model, manufactured by Sound Metrics, Corp., operated at 0.7 MHz, controlled by DIDSON V5.26.06 software on a laptop computer,
3) A Sound Metrics 60 m DIDSON cable,
4) Sound Metrics 30 m and 150 m ARIS cables,
5) A Sound Metrics model X2 rotator, configured to control pan and tilt via ARIScope software,
6) A manually operated rotator, controlling tilt, and

7) A Sound Metrics model AR2 rotator, configured to control tilt and roll via ARIScope software.

Because of equipment failures, 3 different sonar setups were used on the right bank in 2013. For the initial setup, the ARIS was connected to the X2 rotator which was mounted to an aluminum rectangular pod (Figure 6) and the 60 m DIDSON cable connected the equipment to the laptop computer. The second setup consisted of the ARIS, manually operated rotator, and 30 m ARIS cable. The third setup consisted of the DIDSON, manually operated rotator, and DIDSON cable. In 2014, a single system was used, consisting of the ARIS, AR2 rotator, and 150 m ARIS cable. All components functioned properly for the duration of the 2014 field season.

During the 2013 field season, a wireless system was installed to transfer data from the right bank to the left bank sonar tent. However, there were issues with an inconsistent signal and the system was abandoned midway through the season. For the remainder of the 2013 season, files were initially saved to the right bank laptop hard drive and then transferred to the left bank manually using an external hard drive. In 2014, the wireless system was attempted again using longer cables, which allowed the left bank antenna to be positioned at the edge of the riverbank unobscured by trees. In addition, more powerful routers were used and the resulting system worked without fail throughout the season.

In 2014, the shed that housed the sonar equipment on the right bank was mounted on posts, which brought the height up approximately 2 ft. This improvement allowed the equipment to remain in place during the high water event in the early part of the 2014 season, and data collection continued as scheduled for the majority of this time.

Equipment Settings and Sonar Strata

In 2013, the HTI echosounder was configured for a 0.5 ms transmit pulse width and in 2014, this was changed to 0.4 ms (Table 1) to improve the resolution and for consistency with operations at the Pilot Station sonar project. The receiver bandwidth was automatically determined by the equipment based on the transmit pulse duration. On the left bank, the number and range of strata were adjusted several times throughout the 2013 and 2014 seasons in order to find the optimal configuration based on attenuation, river bottom profile, length of fish traces, horizontal range distribution of fish, and test fishing ranges. A configuration of 3 strata with ranges of 50 m each was ultimately selected for the left bank. The pulse repetition rate for each stratum was adjusted according to the maximum range of the stratum.

In 2013, the high frequency mode (1.2 MHz) was tested with the ARIS early in the season. However, at this frequency there was poor detection at far ranges, therefore the mode was changed to low frequency (0.7 MHz) for the remainder of the 2013 season, and again used throughout the 2014 season (Table 2). On the right bank, configurations of 1 and 2 strata were tested in 2013 in order to determine the optimal configuration based on river bottom profile, horizontal range distribution of fish, and length of fish traces. A configuration of 2 strata with ranges of 20 m each was ultimately selected for the right bank. When using the ARIS, the *maximum* option was always selected for the *frames per second* setting, and the rate for the *frames per second* differed according to the range of each stratum. An issue that arose in 2013 and persisted into 2014 involved the ARIScope program malfunctioning. The frequency of these incidents was reduced by selecting the *fixed* option for the *samples per beam*, setting the *samples per beam* to 1,024, and not collecting vertical files in sequence with horizontal files (the program would frequently crash when switching between a horizontal file and a vertical file).

Sonar Deployment and Operation

In 2013, the left bank sonar transducer was located at 64°58.54′N, 150°49.58′W. In 2014, it was moved several times both upstream and downstream to maintain an acceptable bottom profile, but remained within a distance of approximately 100 m from the 2013 location. The right bank sonar transducer was located at 64°58.68′N, 150°49.75′W in 2013, and was moved once, approximately 12 m upstream from this initial location. In 2014, the right bank sonar transducer was located approximately 5 m downstream from the initial location in 2013.

The sonar pods were deployed in approximately 1.0 to 1.5 m of water; the left bank pod was located approximately 10 m from shore and the right bank pod approximately 3 m from shore. The pods were oriented perpendicular to the direction of current to optimize fish detection. In order to direct fish offshore and into the ensonified water column, fish leads were installed on each bank approximately 1 m downstream from the sonar pods, blocking fish passage from the shoreline to a point slightly beyond the near field blanking range. The blanking range extended 2 m from the split-beam transducer face, and 0.7 m for the ARIS. Tripod and picket fixed weir panels were used to build the fish leads on both banks in 2013 and in the early season of 2014 (Figure 7). Later in the 2014 season, T-stakes, orange plastic fencing, and an old small-mesh seine net were used to construct the nearshore portion of the left bank fish lead.

In 2013, the left bank sonar was operated from July 13 through September 23, and the right bank sonar from July 14 through September 17 (Table 3). Sonar operation started nearly a month later than the optimal start date of June 20 due to initial camp construction, and ended before the salmon runs were fully complete due to project budget constraints. Because of equipment failures, there were short periods of time in 2013 when the sonars did not operate (Figure 8). From September 17 through September 23, the ARIS was used to observe fish behavior at the fish wheel and perform a side-by-side comparison with the split-beam sonar on the left bank.

In 2014, both the left and right bank sonars were operated from June 26 through September 25. Sonar operation started approximately 1 week later than the optimal start date due to near-flood conditions, and ended before the salmon runs were fully complete due to project budget constraints. The left bank sonar did not operate on June 29, and the right bank sonar did not operate on June 30, because of high water and debris loads.

At the beginning of each sonar shift, technicians verified rotator positions and checked the sonar recording windows to ensure that the images looked consistent with the initial aim. Equipment settings were verified each time the sonar was re-aimed, and recorded in logbooks. One issue that arose with the split-beam sonar involved the file times slowly drifting with each change in stratum. To compensate for this, the sonar recording was stopped every few days and restarted at either 0 or 30 min past the hour, to maintain file times that closely corresponded to the first and second half of the hour. In 2013, silt was cleaned from the ARIS and DIDSON lenses 5 times. In 2014, the ARIS lens did not require cleaning because of tight sealing performed by the manufacturer prior to the field season.

Standard Target

Standard target data collection was performed in 2013 to verify that the calibration parameters for the split-beam sonar were correct for the sounder, transducer, and cable configuration used. An HTI model 671 38.1 mm diameter tungsten carbide sphere was suspended from a pole with monofilament line, lowered until it touched bottom, and then raised 1 to 2 ft. The target was deployed from shore at 3 m from the transducer, and from an anchored boat at 10, 25, and 30 m from the transducer. At each distance, the transducer was aimed directly at the sphere and the average target strength was measured using Polaris software (version 2.0). Most ranges at which the target was deployed exceeded a distance twice the nearfield, which is approximately 4 m for a 2.8° transducer transmitting and receiving at 200 kHz. The system gain (G1) parameter was adjusted so that the measured target strength of the sphere was approximately equal to -40.0 dB, the calculated value for an ideal receiver at 200 kHz (Simmonds and MacLennan 2005).

Aiming

The sonar pods were moved frequently throughout the 2013 and 2014 field seasons due to changes in the water level and river bottom profiles. Each time the pods were moved, the transducers were re-aimed in order to optimize fish detection. The HTI system had 2 rotators, 1 of which controlled the pan of the transducer, and the other the tilt. Both rotators were controlled remotely via the rotator controller in the sonar tent. To obtain the optimal aim, the HTI transducer was panned horizontally 15° upstream and downstream of perpendicular, in 2° increments. Echograms were inspected for consistent bottom returns throughout the entire range, indicating that the sonar beam was skimming the substrate, and to find an area with minimal dips and mounds, to ensure complete ensonification of the areas fish were expected to primarily travel. Once the optimal pan was determined, the tilt was refined for each stratum by making adjustments of 0.5° to 1.0°. Files were recorded while adjustments were made, so that echograms could be inspected and an optimal aim could be selected.

In 2013, the X2 rotator was configured to control pan and tilt, and the positions were adjusted in the ARIScope program. An initial aim was found by setting the range to approximately 40 m, and then panning and tilting the transducer until bottom features appeared in most of the ARIScope video window. The tilt was then refined for each stratum by making adjustments in 1° increments. Files were recorded while adjustments were made, so that echograms could be inspected and an optimal aim could be selected.

The manually operated rotator only had the ability to control the tilt of the transducer, with a fixed pan dependent upon the positioning of the sonar pod. When this rotator was used, 1 person would manually turn the crank, and another person would watch the ARIScope video window. An optimal tilt was obtained when bottom features appeared in most of the video window. If it appeared that there were large dips or mounds in the profile, the entire pod was manually shifted by a small amount, and then the tilt was refined again. These steps were continued until an acceptable aim was obtained.

The field of view of the ARIS was 14° tall by 28° wide. When rotated 90°, the wide axis of the field of view was oriented vertically and could be used to collect vertical fish position data. The AR2 rotator could be mounted multiple ways, allowing for several options to control the pan, tilt, and roll of the ARIS. The stable bottom profile and consistent slope on the right bank, and the ability to manually shift the pod to adjust the pan, made it unnecessary to mount the AR2 to control the pan axis. Instead, in 2014, the AR2 was configured to control the tilt and roll, which allowed for collection of vertical position data throughout the season. When aiming, the optimal pan was obtained by manually shifting the position of the entire pod, and the optimal tilt was obtained using the same method described above for the X2 rotator. Once the optimal aims were found for the standard horizontal stratum, a third file type was configured in ARIScope and the aim was determined for collecting vertical distribution files. For these files, the range was set to 40 m and the ARIS roll was set to -90°.

Sampling Plan

The sonar was operated 24 h per day. Left bank sonar files were collected in 30 min increments, alternating between strata. When the sonar was configured for 2 strata, 12 h of data were collected per stratum; when it was configured for 3 strata; 8 h of data were collected per stratum. On the right bank in 2013, when the sonar was configured for 1 stratum, new files started at the top and bottom of each hour for 30 min each. When the sonar was configured for 2 strata, the nearshore files started at the top of the hour and the offshore files at the bottom of the hour, for 30 min each. In 2014, vertical distribution files were added to the sampling plan. The nearshore files began at the top of the hour for 30 min, offshore files began at the bottom of the hour for 20 min, and vertical files started at 50 min past the hour for 10 min.

Marking Files

Fish were marked on project laptops using Echotastic software (version 3) developed by ADF&G (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks), and a record was kept of each fish, including the range and time stamp. Technicians were instructed to mark the beginning of each trace as the fish entered the sonar beam. The digital sampling used by both the ARIS and split-beam sonars eliminates the use of thresholds, and all echoes were recorded in the digital files. However, thresholds were applied to files when viewed in Echotastic to reduce background noise and improve visual detection of fish traces. When suspended sediment levels were high, the thresholds in Echotastic were lowered to compensate for increased attenuation. The lower threshold setting on the left bank ranged between -80 dB and -45 dB, and on the right bank between -60 dB and -15 dB, depending on the signal attenuation at the time (Table 4).

After files were marked in Echotastic a text file was saved that included the date, file start time, total file time, total number of marks, and a time stamp and range for each mark, among other data. In addition, technicians recorded file information on paper data sheets for quick reference and quality control purposes (Appendix A1). Sonar text files were saved in folders according to bank and stratum, where they could be accessed by the *R* computing software (version 3.2.2, R Core Team 2015) to generate the daily passage estimates.

Additional Investigations

Nearshore Detection

To assess whether fish were going undetected in the nearshore region of the left bank (due to the substantially narrower beam of the HTI transducer) the ARIS transducer was deployed next to the HTI transducer from September 20 through September 23 in 2013. In 2014, the DIDSON transducer was used for the same comparison from August 19 through August 22, and again on September 21. The counts of the 2 systems were compared within the 0 to 40 m range. The detectability of fish in the offshore region of the ARIS range was also assessed. For the analysis, a total of 26 DIDSON files from 2014 were marked postseason by a single individual and counts were compared to the HTI files marked by technicians during the regular season. The 2014 DIDSON files were marked a second time after changing a setting in Echotastic that increased the number of center beams used to generate the echogram from 4 to 25 to assess whether this setting had an effect on detection. Any changes in the counts were noted.

Vertical Distribution

Vertical distribution files collected in 2014 on the right bank were processed postseason by a single individual. Files were selected from days that fit into 1 of 4 categories: summer season low water (July 22), summer season high water (July 9), fall season low water (September 14), and fall season high water (September 4). Fish targets and bottom profiles were marked using DIDSON software. The range and bearing for each mark, and the pitch of the transducer, were used to calculate the location in the water column in relation to the river bottom. From July 22 a total of 207 targets were marked in 9 files, from July 9 a total of 163 targets were marked in 6 files, from September 14 a total of 326 targets were marked in 7 files, and from September 4 a total of 120 targets were marked in 12 files. Vertical distribution data were not collected on the left bank in this study.

Fish Behavior

In 2014, a DIDSON sonar was used from September 22 through September 23 to observe fish behavior near the sonar fish leads, to see whether fish were cutting tight corners around the fish leads and passing behind the sonar undetected. The DIDSON was positioned upstream and nearshore of the sonar pod already in place on each bank, and then angled to capture an image of both the pod and the outer end of the offshore weir panel. A total of five 30 min files per bank were viewed postseason and qualitative fish behavior was noted.

SPECIES APPORTIONMENT

Fish Wheel

Observation of submerged debris during site work in 2012 suggested drift gillnetting might be difficult or unsafe on the left bank (Figures 9 and 10). This was consistent with results from the study in 1990 (LaFlamme 1990). Fish wheels are a traditional method for catching salmon in the Tanana River, and it was proposed that a fish wheel could be a viable option for test fishing at the site on the right bank. It was also postulated that if drift gillnetting did not prove feasible on the left bank, the fish wheel catches could potentially be used to apportion counts on both banks, if species proportions were similar.

There were no fish wheels available in the Manley Hot Springs vicinity that could be leased for the study, so ADF&G contracted Manley Hot Springs resident Steve O’Brien to build a fish wheel. The raft, axle, and basket were constructed from locally available spruce logs and poles (Figure 11). To minimize handling stress and impact on captured fish, features developed in similar wheels (Rapids Research Center 2015) were incorporated into the design of the new wheel. The height of the livebox chute was adjustable (with the raising or lowering of the axle) to minimize fish drop from the basket chutes, and the livebox chute supports were flexible, which reduced fish impact. The basket frames were constructed strong enough so that additional side bracing was minimal, reducing the number of structures that fish could hit; and wire, nails, and other sharp construction materials were covered or used in a manner that would not cause injury to the fish. The basket beds were constructed with smooth, vinyl-coated crab pot wire, and the bottom and sides of the basket chutes were padded with foam. The sides of the baskets were constructed with 2.25 in stretch knotless seine mesh, and the bottom of the livebox chute was layered with smooth, ultra-high molecular weight (UHMW) plastic. In addition, the livebox had a water volume of approximately 75 cubic ft, and was constructed with several small holes in the sides, allowing a high flow of water through the livebox.

The fish wheel was deployed on the right bank approximately 638 m downstream from the right bank sonar, at 64°58.60′N, 150°50.55′W, a distance assumed adequate for migrating fish to resume normal behavior when they reached the sonar site. The fish wheel was built large in order to fish in deeper water further offshore. The length of the spar log was 46.5 ft, positioning the wheel in approximately 12 ft of water and giving the wheel a horizontal range of coverage of approximately 20 m. With changing water levels, the fish wheel was regularly sparred in towards, or away from, the shoreline to fish at a consistent depth, and to maintain a minimal gap between the basket and livebox chutes. Each day the baskets were adjusted to sweep just above the bottom. A fish lead constructed of spruce pole panels was installed approximately 1.5 m downstream from the axle. The offshore lead panel extended beneath the fish wheel raft to minimize the distance between the lead and the baskets. In 2013, at the suggestion of the contractor, approximately 5 m of space was left open between the nearshore lead panel and shoreline, for ease of clearing debris. On July 31, 2014, an additional lead panel constructed of spruce poles and orange plastic fencing, and a 2.25 in stretch mesh size seine net, was added to block this area to fish passage all the way to the shoreline.

In 2013, the fish wheel was operated every day from July 16 through September 23, for an average of 9 h per day. Fish wheel operation started nearly a month later than the optimal start date of June 20 due to the initial camp construction, and ended before the salmon runs were fully complete due to project budget constraints. The fish wheel was not operated at night for safety reasons and to prevent fish from being held in the livebox for extended periods of time. The livebox door was closed when the fish wheel was started in the morning, and fish were dipped from the livebox and sampled approximately every 3 hours.

In 2014, the fish wheel was operated from July 11 through September 23, but not on August 4 due to needed repairs. Fish wheel operation started nearly 3 weeks later than the optimal start date due to near-flood conditions and high debris loads, and ended before the salmon runs were fully complete due to project budget constraints. Before the video system was installed, the fish wheel was run for an average of 8 h per day, and fish were dipped and sampled from the livebox as in 2013. The video system began operating on July 23, and was tested and refined through August 21. On August 22, continuous 24 h sampling was started, and for the remainder of the field season the fish wheel operated for an average of 20 h per day. The fish wheel was only stopped to clean debris and perform necessary maintenance. During this time period, the livebox door was closed in the morning until the daily ASL sample size was met, after which the door was opened and the video files were used to count the catches for the remainder of the day. Fish wheel run time and catch data were recorded on paper data sheets (Appendix A2).

Fish Wheel Video System

In 2014, ADF&G contracted Dave Daum to build a video system for the fish wheel that would allow it to run 24 h per day, and minimize the time fish spent in the livebox. The video system had several components. An adjustable-height, flexibly supported video chute was constructed for the fish wheel and lined with white UHMW plastic. A swinging trapdoor was mounted on the livebox side of the chute, with a magnetic switch that triggered the recording of frames when the trapdoor opened as a fish slid through. A Panasonic Color CCTV camera, model WV-CP474, inside a waterproof protective housing, was mounted on the top of the chute and aimed down. Two lights were positioned above the video chute (1 powered by batteries, 1 by the generator) to illuminate fish at night and a light sensor was installed to control when the battery-powered light turned on and off. A laptop computer was used to run SalmonSoft FishCap software (version

1.4.0) for recording files, and MGI VideoWave III software (version 3.5) for adjusting the colors of the video image. The equipment was powered by a battery bank consisting of three 12 V batteries with an inverter, and a 2,000 W Honda generator was used to charge the battery bank and power the equipment in the evenings when natural light was insufficient.

The video system was operated from July 23 through September 23. From July 23 through August 19 the FishCap program was configured to save one 24 h file per day. From August 20 through September 23 the settings were changed to save two 12 h files per day, to simplify file transfer and better correspond with the crew schedule. Video files were saved to the hard drive on the laptop computer, and then manually transferred to the left bank sonar tent using an external hard drive. Files were viewed and counted using SalmonSoft FishRev software (version 1.4.3), and catch data were recorded on paper data sheets.

Gillnets

Although drifting gillnets is the preferred method of capturing fish in the current of the main channel, an attempt was made to set gillnets in the event submerged debris prevented drifting on the left bank. All gillnets used measured 25 fathoms in length, were hung at a 2:1 ratio of mesh to corkline, and were constructed with multistrand monofilament nylon shade 11 twine. Two net depths, approximately 13 ft and 26 ft, were drifted on both banks in order to compare the effectiveness of each. The shallow (13 ft) nets were used for the set nets. Five different stretch mesh sizes (2.75, 4.0, 5.25, 6.5, and 7.5 in) were used in order to catch all sizes of fish that could be detected by the sonar. Drift gillnets were deployed with a skiff driving offshore to nearshore, and were fished as perpendicular to current as possible. Set nets were deployed with a skiff, and the offshore end of the set net was secured with an anchor. Because of the current at the set net sites, the offshore ends of the nets angled downstream to varying degrees. The perpendicular distance from the offshore end of the set net to shore ranged from approximately 19 to 48 m in 2013, and 9 to 34 m in 2014.

In 2013, drift gillnets were fished sporadically from August 5 through September 11 because methods were being refined, resulting in low catches in August and early September. Drift gillnets were fished consistently from September 12 through September 23. Set gillnets were fished from September 10 through September 23. Gillnet fishing started over a month later than the optimal start date of June 20, due to the initial camp construction, and ended before the salmon runs were fully complete due to project budget constraints. A single nearshore zone was drifted on the right bank and nets deployed as close to shore as possible (Figure 12). Initially, the right bank drift was performed directly in the vicinity of the sonar and started approximately 230 m upstream from the right bank sonar, and ended approximately 100 m upstream from the fish wheel. This site was fished for 4 days, after which it was abandoned because of difficulty avoiding the sonar pod and fish wheel with the swift current, and the short total drift time. The drift site was relocated to start approximately 2.9 km downstream from the fish wheel at 64°58.50′N, 150°54.17″W and ended approximately 630 m further downstream.

On the left bank, all drifts were conducted in front of the sonar deployment location with 2 zones, a nearshore and an offshore. Drifts started approximately 75 m upstream and ended approximately 225 m downstream from the left bank sonar. For the nearshore zone, nets were deployed as close to shore as possible, and for the offshore zone, nets were deployed approximately 1 net length offshore from the transducer.

The deep (26 ft) nets were drifted intermittently from August 5 through September 4 in the right bank nearshore and left bank offshore zones. Shallow (13 ft) nets were used for all other times and zones. Initially, the drift gillnets were fished in the nearshore zone on the left bank. However, because of difficulties with submerged debris in this area, this method was discontinued. Starting on September 10, set nets were used to cover this zone and were used for the remainder of the season.

Two set net sites were attempted on the left bank. The first was located approximately 140 m upstream from the sonar. However, it was within close proximity to the net racks, and after a few days the set net site was moved downstream approximately 45 m to avoid disturbance from the test fish boat swapping out nets. Only 1 set net site was tested on the right bank approximately 1.8 km downstream from the fish wheel at 64°58.57′N, 150°52.86′W, but it did not prove effective and was discontinued.

In 2014, drift gillnets were fished from June 26 through September 25, and set gillnets were fished from June 26 through July 27. Gillnet fishing started nearly a week later than the optimal start date due to near-flood conditions early in the season, and ended before the salmon runs were fully complete due to project budget constraints. The downstream right bank drift site used in 2013 was fished for the entirety of the 2014 field season. The left bank drift site was similar to that used in 2013, but the start of the drift was moved upstream approximately 100 m. The zones remained the same as in 2013; however, the set nets were only used in the left bank nearshore zone for the early part of the season and were then replaced by the drift gillnets. High water and a dynamic bottom profile at the site made set netting difficult and ineffective, and a reduction in snags in the zone made drifting possible.

Deep (26 ft) nets were drifted intermittently from July 4 through July 18 in the right bank nearshore and left bank offshore zones. Shallow (13 ft) nets were used for all other times and zones. A large difference in water velocity between the left bank nearshore and offshore zones of the drift gillnets occasionally caused the nets to drift at an angle that was not perpendicular to the direction of current. To reduce this effect, setting out approximately half the net length was tested intermittently on both banks from July 17 through July 31.

Two set net sites were used on the left bank; the first was at the same location as the downstream site used in 2013, and the second was located approximately 25 m further downstream. Setting out part of the net length was also tested for the set nets from July 2 through July 31 to ease deployment and reduce the amount of debris caught. In addition, a boom log was deployed off the left bank shore and tested from July 4 through July 13 in an attempt to reduce the current and debris at the set net site, and assist in holding the net perpendicular to current.

The net schedule was revised several times throughout the 2013 and 2014 seasons as project methods developed. Two periods were fished per day. At the end of the 2013 season and beginning of 2014, the right bank nearshore and left bank offshore zones were each drifted with the suite of mesh sizes during 1 period per day. For the left bank nearshore zone, each mesh size was set once per day. The net schedule rotated so that mesh sizes were not fished in the same order every day. During the second half of the 2014 season, the set nets were discontinued, and all 3 zones were drifted during both periods each day. Each period, 4 mesh sizes were fished and the order was rotated daily (Table 5). Drift and catch data were recorded on paper data sheets (Appendix A3).

Biological Sampling

Captured fish were identified to species and measured to the nearest 1 mm length. Salmon species were measured from mid eye to tail fork (METF), and non-salmon species were measured from snout to fork of tail (FL). Sex was determined for all salmon species by observing external characteristics. In 2014, 3 to 4 scales were collected from each of 68 Chinook salmon for age determination.

Initially in 2013, every fish captured in the fish wheel was measured for length. On September 4, length subsampling for chum and coho salmon was started, and 30 chum and 20 coho were measured per day for the remainder of the field season. In 2014, a subsample of 10 chum and 10 coho per day were measured for length.

Data Entry

All catch data were manually entered into a Microsoft Access database. Each day the cumulative data set for the season was exported as a *.csv file to be accessed by the *R* computing software for generating daily passage estimates.

Fish Behavior

In 2013, the ARIS was used from September 17 through September 19 to investigate fish behavior near the fish wheel. The pod was deployed close to shore approximately 2 m downstream from the fish lead, and the ARIS was aimed diagonally toward the fish leads and baskets. The range was set to approximately 20 m, and extended approximately 4 m beyond the baskets. In 2014, the DIDSON was used similarly from September 12 through September 15, and was deployed approximately 6 m downstream from the fish lead. Three angles and ranges were used. For the first, the DIDSON was aimed at the nearshore region of the fish leads, with a range of approximately 20 m. Next, the DIDSON was aimed at the offshore region of the fish leads and baskets, with a range of approximately 20 m. Lastly, the DIDSON was aimed to view the offshore region of the leads, baskets, and approximately 22 m beyond the baskets, with a range of approximately 40 m. A total of 6.3 h of ARIS video from 2013 and 8.5 h of DIDSON video from 2014 were viewed postseason and qualitative fish behavior was noted.

HYDROLOGICAL SAMPLING

Water Temperature

Water temperature was recorded on both banks from August 31 through September 23 in 2013, and from June 26 through September 25 in 2014. Waterproof Onset HOBO Water Temperature Pro v2 data loggers were attached near the base of each sonar pod and deployed at a depth of approximately 1 to 1.5 m. The data loggers were configured to record at 1 h intervals. In 2014, the temperature was also measured manually at a depth of approximately 0.5 m on each bank twice per day using an Enviro-Safe “Easy Read” Armor Case thermometer, to have a backup in the event that the data loggers were lost or malfunctioned.

Suspended Sediment

To investigate the effect of suspended sediment on signal attenuation, Imhoff cone testing was performed from August 6 through September 22 in 2013, and from June 28 through September 23 in 2014. On each bank, approximately 10 m offshore from the sonar transducers, 1,000 mL of water were collected approximately 1 ft below the surface each day. Water samples were mixed and poured into Imhoff settling cones. In 2013, 1 set of cones was used and 2 sets of cones were used in 2014. Settled solids were measured to the nearest 0.1 mL at 1 h and 24 h after the samples were transferred to the cones. Suspended sediment levels were plotted with water level, and clarity of sonar images was noted throughout the season. Only suspended sediment data collected in 2013 were used for the analysis because of inconsistent data records in 2014 that resulted from the 2 sets of cones.

ANALYTICAL METHODS

Daily estimates were produced from the following:

1. Sonar estimates of all fish targets passing the site, without regard to species.
2. Species composition estimates derived from test fishery results and applied to the sonar estimates.

Sonar Estimates

Daily sonar passage for each stratum (y_{ds}) was estimated by expanding each hourly count to a full hour, averaging the hourly passage rates for the day, and then multiplying by 24 hours:

$$\hat{y}_{ds} = 24 \bullet \frac{\sum_{h=1}^{n} \frac{y_{dsh}}{f_{dsh}}}{n_{ds}}, \tag{1}$$

where y_{dsh} is the count for hour (h) of stratum (s) on day (d), f_{dsh} is the fraction of the hour sampled for hour (h) of strata (s) on day (d), and n_{ds} is the total number of samples for the strata on that day. Sonar estimates were spaced at regular (systematic) intervals of 1 hour. Treating the systematically sampled sonar counts as a simple random sample could yield an overestimate of the variance of the total because sonar counts are highly autocorrelated (Wolter 1985). To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed.

$$\hat{V}ar(\hat{y}_{ds}) = 24^2 \bullet \left[1 - \frac{h_{ds}}{24}\right] \frac{\sum_{h=2}^{n} \left(\frac{y_{dsh}}{f_{dsh}} - \frac{y_{ds,h-1}}{f_{ds,h-1}} \right)^2}{2n_{ds}(n_{ds}-1)}, \tag{2}$$

where h_{ds} is the total number of hours sampled for stratum (s) on day (d). Sonar files with a total time of less than 10 min were not used to generate daily passage estimates, to reduce bias associated with low or variable fish passage rates.

Fish Passage by Species

Three zones, corresponding to sonar strata, were fished: the right bank nearshore, left bank nearshore, and left bank offshore. However, the right bank drift gillnets and fish wheel were treated as separate zones (even though they covered approximately the same area), which resulted in a total of 4 zones. This was done because the fish wheel and gillnet catches could not be easily combined to generate a single proportion due to differences in catch efficiency of the 2 gear types, and it allowed either method to be used if one was not able to operate. Only the catches from 1 method were used to apportion the right bank sonar counts on any given day.

The fish wheel catches were used to apportion the right bank counts for most days throughout the 2013 and 2014 seasons, except for days when it was not operating, and on those days the right bank drift gillnet catches were used. Fish wheel catches were primarily used because the fish wheel operated more consistently than the drift gillnets. A quantitative analysis comparing the estimates generated by each method was not performed in this study.

For calculations, Zone 1 was assigned to the right bank drift gillnets and Zone 4 was assigned to the fish wheel, each consisting of the entire counting range for the right bank. Zone 2 consisted of the single nearshore stratum on the left bank, and Zone 3 consisted of the offshore stratum on the left bank. Sonar stratum were paired with the most appropriate test fishery zone for each day (Appendices B1 and B2).

Species composition estimates were calculated on the basis of report units (encompassing 1 or more full days of sampling in a zone), and then applied to the daily sonar estimates. For any test fishery variable (x) the report unit (u) encompassed days (d), test fishery periods (j), and zones (z) such that:

$$x_u = \sum_{d,j,z}^{u} x_{djz} \ . \tag{3}$$

Any unique combination of day and zone having sufficient test fishery catch (at least 2 periods with 1 or more fish each) was assigned a unique report unit (u), and combinations without sufficient catch were pooled by assigning the same report unit across days (Appendices C1 and C2).

Duration of the drift or set gillnet sampling period (j) in minutes (t) was calculated as:

$$t_j = (SI_j - FO_j) + \frac{(FO_j - SO_j)}{2} + \frac{(FI_j - SI_j)}{2} \ , \tag{4}$$

where SO is the time the net was initially set out, FO is the time the net was fully set out, SI is the time the net started back in, and FI is the time the net was fully retrieved.

To estimate species proportions for report unit (u), first the total effort (f) (in fathom-hours) of sampling period (j) with mesh size (m) during report unit (u) was calculated by multiplying the sampling time (t) for each drift or set gillnet sampling period by 25 fathoms and dividing by 60 min per hour,

$$f_{umj} = \frac{25 \cdot t_{umj}}{60} \ . \tag{5}$$

Total effort for each mesh size fished was summed over each report unit,

$$f_{um} = \sum_{j} f_{umj} \ , \tag{6}$$

and the catch of species (i) of length (l) in each report period was summed across all mesh sizes.

$$c_{uil} = \sum_{m} c_{uilm} \ . \tag{7}$$

For the catch of each species (i) of length (l), the associated effort was adjusted by applying a length-based selectivity parameter S derived from the Pearson T net selectivity model (Appendix D1) (Bromaghin 2004).

$$f'_{uil} = \sum_{m} \left(S_{ilm} \cdot f_{um} \right). \tag{8}$$

The catch per unit effort (CPUE) of the catch of each species (i) of length (l) was calculated as:

$$CPUE'_{uil} = \frac{c_{uil}}{f'_{uil}}. \tag{9}$$

The proportion (p) of species (i) during report unit (u) was estimated as the ratio of the CPUE for species (i) to the CPUE of all species combined.

$$\hat{p}_{ui} = \frac{\sum_{l} CPUE'_{uil}}{\sum_{i,l} CPUE'_{uil}}. \tag{10}$$

The same set of equations was used to calculate the fish wheel proportions with 2 notable differences. Theoretically, the fish wheel was designed to capture any fish that encountered the baskets, and the net selectivity parameter was set to 1.0 for all fish captured in the fish wheel. This assumed equal probability of capture regardless of species, sex, or size. Although there may have existed some form of capture bias, the source and nature of that bias was not explored in this study. In addition, operational time was calculated as the stop time minus the start time, because there was insignificant lag in starting and stopping the fish wheel. This was done by setting the SO equal to FO and SI equal to FI (Equation 4).

The variance was estimated from the squared differences between the proportion (p) of each test fishery period (j) for each day (d) within the report unit (u), and the proportion for the report unit as a whole:

$$\hat{Var}(\hat{p}_{ui}) = \frac{\sum \left(\hat{p}_{ui} - \hat{p}_{udxi} \right)^2}{n_u \cdot \left(n_u - 1 \right)}, \tag{11}$$

where n_u is the number of test fishery sampling periods within the report unit.

The passage of species (i) in stratum (s) was estimated for each day as the product of the species proportion (Equation 10) for the report period containing day (d) and the total sonar passage for the day (Equation 1).

$$\hat{y}_{dsi} = \hat{y}_{ds} \cdot \hat{p}_{udi}. \tag{12}$$

Except for the timing of sonar and test fishery sampling periods, sonar-derived estimates of total fish passage will be considered independent of test fishery-derived estimates of species proportions. Therefore, the variance of their product (daily species passage estimates by strata (y_{id})) was estimated as the variance of the product of 2 independent random variables (Goodman 1960).

$$\hat{V}ar\left(\hat{y}_{dsi}\right) = \hat{y}_{ds}^{2} \cdot \hat{V}ar\left(\hat{p}_{ui}\right) + \hat{p}_{ui}^{2} \cdot \hat{V}ar\left(\hat{y}_{ds}\right) - \hat{V}ar\left(\hat{y}_{ds}\right) \cdot \hat{V}ar\left(\hat{p}_{ui}\right) \ . \tag{13}$$

Passage estimates are assumed independent between reporting units and the variance of their sum was estimated by the sum of their variances.

$$\hat{V}ar\left(\hat{y}_{si}\right) = \sum_{d} \hat{V}ar\left(\hat{y}_{dsi}\right) \ . \tag{14}$$

Problematic Data

During the initial test fishery training period in 2013, technicians occasionally neglected to record drift times or other data. Records missing essential data that could not be estimated (e.g., bank) were omitted from the database. Records missing data that could be reasonably estimated (e.g., times) were included in the database, and missing values were estimated. To estimate times, the average set-out time, soak time, and pull-in time for all complete drifts and sets were calculated, and missing times were entered to match these averages, accordingly.

While drift gillnetting, in cases when snags were caught and the net quickly became ineffective, technicians would begin to retrieve the net. Entering the *start in* and *full in* times as for a normal drift resulted in this period of ineffective fishing being included in the total fishing time. To reduce bias in the CPUE associated with snags, data recording and entry was modified so that the time the snag was initially caught was recorded as the *start in* time, and the time the net folded and stopped fishing effectively was recorded as the *full in* time. For snagged drifts that occurred before this change in methods, the *full in* time was adjusted in the database to equal the *start in* time for these records, thereby eliminating the portion of the drift during which the net was not fishing properly.

In a few instances fish escaped from the test fishery boat before a length was recorded. The net selectivity model used to calculate species proportions requires a length measurement for fish caught in the gillnets; therefore, these fish were excluded from the database.

In September 2014, 3 cisco and 2 longnose sucker caught in the 2.75 in mesh net, and 1 sheefish caught in the 7.5 in mesh net, had lengths that fell near the tail end of the selectivity curves, resulting in high other species estimates for the day. These estimates are probably over-exaggerated by the selectivity model used for the calculations, and do not accurately reflect true fish passage. A change to the selectivity model is being developed, but, for data processing in the meantime, rather than modify the model's *R* code to accommodate these rare events, the lengths of these fish were changed in the Microsoft Access database to equal the length of a fish with a selectivity of 1 for the mesh size in which the fish was caught.

There were occasions during both the 2013 and 2014 seasons when test fishing did not occur, or the catches were too low (typically in the left bank offshore zone) to accurately estimate species proportions and associated error bounds. Drift and set gillnetting were not started until late in the 2013 season, and there were several days without left bank catches. During the 2013 season and early in the 2014 season, the net schedules only allowed for the left bank offshore and right bank nearshore drift zones to be fished once per day. In addition, there were often sparse catches during periods of low fish passage, especially in the left bank offshore zone. When sufficient catches were not available for a given day and zone, the data were pooled with data from 1 or more adjacent days by assigning them the same report unit. To address the late fishing start in

2013, all sonar counts prior to the start of fishing were assigned to the reporting unit of the first fishing periods, within their respective zones.

On the left bank in 2014, from July 4 through July 13 and July 22 through July 26, the nearshore set net was not fishing optimally, and the range did not sufficiently correspond to that of the left bank nearshore sonar stratum. During these time periods, the left bank offshore catches were used to apportion the left bank nearshore sonar estimates.

There were short periods of time during the 2013 and 2014 seasons when 1 of the sonars did not operate because of equipment failures, additional studies, or near-flood conditions. On days when there were no sonar files for a given bank, estimates were not generated for that bank.

Nearshore Detection

Standard linear regression was used to compare the split-beam and DIDSON counts.

RESULTS

SONAR ESTIMATES

In 2013, 475,535 fish were estimated to have passed the sonar site between July 13 and September 23 (Appendix E1), 244,234 (51.4%) on the left bank, and 231,301 (48.6%) on the right bank (Figure 13). Estimates are considered incomplete due to the late project start and early termination. On the left bank, 90% of fish passed within 20 m of the transducer during the summer season and within 80 m during the fall season (Figure 14). On the right bank, 90% of fish passed within 10 m of the transducer during the summer season and within 12 m during the fall season.

In 2014, 504,281 fish were estimated to have passed the sonar site between June 26 and September 25 (Appendix E2), 164,205 (32.6 %) on the left bank, and 340,076 (67.4 %) on the right bank (Figure 15). Although the project started a week later than planned, these estimates represent a nearly complete season given the low initial passage rates and the mostly continuous sonar operation. On the left bank, 90% of fish passed within 40 m of the transducer during both the summer and fall seasons (Figure 16). On the right bank, 90% of fish passed within 12 m of the transducer during both the summer and fall seasons.

TEST FISHING

The fish wheel covered a range of approximately 20 m. The drift gillnets were approximately 46 m long but were rarely deployed perfectly perpendicular to the current. The right bank sonar covered a range of 40 m, but overall, 95% of fish passed within 16 m of the transducer. Assuming the fish were distributed similarly at the fish wheel and right bank drift zone, both methods sufficiently covered the range in which the majority of fish were traveling.

In 2013, the drift gillnets were fished for a total of 20.7 h, the set gillnets for 63.8 h, and the fish wheel for 624.9 h (Table 6). A total of 7,115 fish were captured in the test fishery (Table 7). Fall chum salmon was the predominant species proportion in Zones 1, 3, and 4, and fish of other species was the predominant proportion in Zone 2 (Table 8). Because data collection started late and gillnet fishing was initially inconsistent, some of the early Chinook and summer chum salmon runs were missed in the right bank test fishery, and were missed entirely in the left bank test fishery. Also, because data collection ended before the salmon runs were fully complete, some of the late fall chum and coho salmon runs were missed. Of the fish captured in the drift gillnets, 136 (23.3%) were retained as mortalities (Table 9), and of those captured in the set gillnets, 18 (18.4%) were retained (Table 10). Of the fish captured in the fish wheel, 21 (0.3%) were retained (Table 11). Retained fish were given to local users. There were approximately equal proportions of male and female Chinook and fall chum salmon; however, there was a slightly larger proportion of female than male summer chum, and a larger proportion of male than female coho salmon (Table 12).

In 2014, the drift gillnets were fished for a total of 170.8 h, the set gillnets for 175.8 h, and the fish wheel for 990.8 h. A total of 17,210 fish were captured in the test fishery. Fall chum salmon was the predominant species proportion in Zones 1 and 4, fish of other species was the predominant proportion in Zone 2, and summer chum salmon was the predominant proportion in Zone 3. Because data collection started late and ended before the salmon runs were fully complete, some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed in the test fishery. Of the fish captured in the drift gillnets, 100 (3.8%) were retained as mortalities (Table 13), and of those captured in the set gillnets, 4 (10%) were retained (Table 14). Of the fish captured in the fish wheel, 26 (0.2%) were retained (Table 15). There were approximately equal proportions of male and female Chinook salmon; however, there were larger proportions of male than female summer chum, fall chum, and coho salmon. The majority (63.2%) of Chinook salmon were age-1.3, having spent 1 year in fresh water and 3 years in salt water (Table 16).

SPECIES ESTIMATES

In 2013, the cumulative passage estimate[2] for Chinook salmon was 2,337 ± 365 (Appendix F1; Figure 17), for summer chum salmon 16,971 ± 447, for fall chum salmon 265,989 ± 14,010 (Figure 18), for coho salmon 40,229 ± 3,463, and for other species 144,662 ± 15,603. Because data collection did not cover a complete season, the passage estimates for Chinook and summer salmon are from right bank only, and all species estimates are considered incomplete. The other species estimate included broad whitefish *Coregonus nasus*, humpback whitefish *C. pidschian*, least cisco *C. sardinella*, sheefish *Stenodus leucichthys*, burbot *Lota lota*, northern pike *Esox lucius*, and longnose sucker *Catostomus catostomus*. The midpoint of the Chinook run occurred on July 17, the summer chum run on July 20, the fall chum run on September 10, and the coho run on September 13 (Appendix G1).

In 2014, the cumulative passage estimate for Chinook salmon was 15,502 ± 2,801 (Appendix F2; Figure 19), for summer chum salmon 165,526 ± 3,770, for fall chum salmon 222,627 ± 5,252 (Figure 20), for coho salmon 61,060 ± 4,055, and for other species 39,564 ± 5,433. Data collection began a week late, and ended before the salmon runs were fully complete, but because initial passage rates were low and the sonar and test fishery operations were mostly continuous, these estimates are considered nearly complete. The midpoint of the Chinook run occurred on July 5, the summer chum run on July 20, the fall chum run on September 11, and the coho run on September 14 (Appendix G2).

The 2013 and 2014 fall chum salmon run timing was very similar, with the 25th, 50th, and 75th percentiles occurring either on the same day, or within 1 day of each other. The 2013 and 2014 coho salmon run timing was also similar, but slightly later in 2014 with the 25th, 50th, and 75th percentiles occurring approximately 2 days later in 2014. The fall chum salmon estimate in 2014

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[2] Cumulative passage estimates for all fish species include 90% confidence intervals.

was approximately 43,000 fish lower than the estimate in 2013. The coho salmon estimate in 2014 was approximately 21,000 fish higher than the estimate in 2013.

ADDITIONAL STUDIES

Nearshore Detection

There was a near 1:1 relationship between the DIDSON and split-beam sonar counts, with the DIDSON counts being slightly higher (regression equation: $y = 1.04x - 0.42$; $R^2 = 0.99$) (Figure 21).

Vertical Distribution

In general, on the right bank, fish tended to swim close to the river bottom during both the summer and fall seasons and during periods of high and low water within each season. However, fish were more tightly concentrated along the bottom during periods of high water, and more dispersed in the water column during periods of low water (Figures 22 and 23).

Fish Behavior

Fish Wheel

The majority of fish were observed encountering the 2 offshore lead panels or basket area, and then either entering the basket area, or swimming offshore and around the baskets. Few fish were observed encountering the nearshore lead panel and seine net area, and few fish were observed swimming at a natural trajectory that was offshore of the baskets. A few fish were observed passing through small gaps in the lead panels or through the narrow space between the offshore lead panel and the baskets.

Sonar Fish Leads

The majority of fish were observed swimming out and around the fish leads at a distance equal to or greater than the sonar near field blanking distance. Occasionally fish angled toward shore after going around the fish leads but remained offshore of the transducers. A few downstream-traveling fish were observed passing very close to the transducer face or behind the transducer. No upstream-traveling fish were observed passing behind the transducer.

HYDROLOGICAL DATA

In 2013, the water level was low in mid-July when data collection began, and then rose to near average for most of the early season (Figure 24). For the second half of the season the water level was mostly above average. Water temperatures ranged from 3.1ºC to 10.7ºC between August 31 and September 23 (Figure 25). The Imhoff cone sediment volumes ranged from 0 mL to 1.4 mL after a settling time of 1 hour, and from 0.4 mL to 4 mL after a settling time of 24 hours. Settled volumes tracked closely with rising and falling water levels (Figure 26).

In 2014, heavy rain in Interior Alaska caused near-flood conditions, and water levels were close to record high from late June through the third week in July. For the remainder of the season water levels were near average, with short periods either below or above average. Water temperatures ranged from 4.7°C to 17.5°C between June 26 and September 25.

River bottom returns were visible throughout the entire sonar range for the majority of both seasons, although the maximum detection range of the split-beam sonar decreased when sediment levels and attenuation were high. Imhoff cone data indicated that suspended sediment levels were closely related to water level. During periods of high water, suspended sediment volumes increased, and bottom stripes and fish traces beyond 110 m on the left bank became difficult to detect. It is possible that this resulted in an underestimate of fish passage. However, when detection was good to 150 m, very few fish were observed beyond 110 m. Total fish distribution shows that 99% of fish passed within 90 m of the transducer; therefore, potential underestimation from reduced detection beyond 110 m should be minimal. Suspended sediment levels did not appear to affect detection of the ARIS or DIDSON with the settings used. However, sediment slowly built up in the ARIS and DIDSON lenses and when this became detectable on the echograms, the lenses were cleaned.

DISCUSSION

Mostly stable water levels in 2013 made for a relatively easy year of sonar and test fishery operations. Early in the 2014 season, the water rose to nearly flood level, which made operations difficult. The high water brought heavy debris loads, which substantially delayed fish wheel deployment and resulted in 1 day of lost sonar data for each bank. However, despite difficulties, the sonar operated the majority of this time, and test fishing continued with drift gillnets. It was encouraging that the project was operational during these extreme conditions.

Minor features of the river bottom profile, primarily on the left bank, changed over the course of the 2013 and 2014 seasons; however, the overall shape of the river bottom at the sonar site remained constant and was acceptable for fish detection. Overall, fish traces were distinguishable and easy to count. On the left bank, setting the range of the nearshore stratum to 50 m worked well, because it corresponded closely with the nearshore test fishery drift, which allowed for simpler data analysis. This configuration also allowed the ping rate to be set higher for the nearshore and mid-shore strata where the majority of fish were distributed, which resulted in longer traces and in turn made for easier counting. Having 2 strata on the right bank resulted in a similar advantage, where the frame rate could be increased for the nearshore stratum, also where the majority of fish were distributed, which resulted in longer traces and easier counting.

Equipment failures during the 2013 season resulted in several periods of lost data. However, these issues were mostly resolved that year, and only a couple days of data were lost due to high water in 2014. Issues that persisted into 2014 included the split-beam file times slowly drifting with each change in stratum, and the ARIScope program malfunctioning, although a few changes to the sonar procedures and settings minimized these issues.

The fixed weir panels worked well for the fish lead on the right bank because the substrate was rocky and firm. Also, the slope was relatively steep and only a few panels were needed. The fixed weir panels worked adequately on the left bank but were much more difficult to deploy and maintain due to the silty substrate. In addition, when the water level was high, due to the more gradual slope, several additional panels were needed to span the distance from shore to the transducer, and the offshore panels were susceptible to falling over due to rapid erosion. During the 2014 season an alternative fish lead, constructed of T-stakes and a seine net, was deployed for the nearshore section on the left bank. This worked adequately but was more difficult to move, collected more debris, and could not withstand strong currents. For future seasons it would be advantageous to rethink the fish lead and develop a better system for the left bank.

Initially in 2013, drift gillnetting was attempted in the left bank nearshore zone, but due to numerous snags, it proved to be ineffective. Low water levels later in the season resulted in a slow current and a small eddy nearshore, so a set net was attempted, and it effectively caught fish. The river conditions during the early part of the 2014 season were drastically different with extremely high water levels, strong current, and an absence of the eddy observed the previous fall, and these conditions prevented the set net from fishing properly. Several attempts were made to improve the set net including moving the location downstream approximately 25 m, deploying shorter sections of net, and installing a boom log to lower the water velocity nearshore and provide a reliable anchor. However, none of these attempts worked and an alternative location could not be found close to the sonar site. Drift gillnetting was attempted again in the left bank nearshore zone, and this time it was effective. It is possible that the near-flood conditions early in the 2014 season removed some of the submerged debris, or alternatively, deposited a large amount of silt covering some of the snags caught during the 2013 season. In addition, a more experienced crew and continual snag removal when possible probably added to the success of the drift gillnetting in the left bank nearshore zone during the 2014 season.

Shallow nets were always used for the left bank nearshore zone, but both shallow and deep nets were tested in the left bank offshore and right bank nearshore zones. The shallow nets proved to be better in nearly all instances because they effectively caught fish but caught substantially fewer snags. The only time the deep nets appeared to be more effective was in the right bank nearshore zone when the water level was extremely high. The slope of the bank above the normal high water level in that zone was very steep, and in these instances the shallow nets only covered the majority of the water column in the first few meters from shore, whereas the deep nets had better coverage over a longer range.

After analyzing the 2013 test fishery data, it became apparent there was an issue with the way snagged drift times were being entered. By entering the actual 4 times, the period during which the net was snagged and not fishing properly was being included and thereby skewed the CPUE. To prevent this, a new procedure was initiated in which the crew would record the time at which the snag was initially caught, and the time at which the net folded and stopped fishing effectively (if the net came off the snag quickly and continued to fish properly, this time was noted as well). In the database, the time the snag was initially caught was entered as the *start in* time, and the time the net folded and stopped fishing effectively was recorded as the *full in* time.

The main advantages to the drift gillnets (relative to the set nets and the fish wheel) were that an adequate sample size could be caught with a reasonable amount of time and effort, the maintenance was relatively easy (though time consuming), and in most instances, they could be operated during times of high debris. However, there were disadvantages involved as well:

1) When passage was low, occasionally there were no catches in a certain zone, or only catches in 1 fishing period. When this occurred, the data from adjacent days were pooled in order to generate a variance estimate. In some instances several days were pooled, which resulted in less accurate point estimates for those days.
2) The snags proved to be manageable but occasionally made for difficult drifting, and resulted in large amounts of time spent mending nets. Due to the high level of wear on nets, money for new nets will probably need to be budgeted each year.
3) Another disadvantage of the drift gillnets was the higher mortality rate versus the fish wheel. However, a live tote was used in the boat and worked well to increase survival rate, especially when catches were high.
4) In addition to the disadvantages, there were some potential sources of bias associated with the drift gillnets. Different species or sizes of fish may have evaded the nets at different rates. The lead line did not always consistently drag bottom along the entire

length of the net for all drift zones (primarily the right bank nearshore zone). The swift current in the right bank drift zone made it difficult to deploy the net and maintain a net shape perpendicular to the direction of flow. Usually, after a few minutes the offshore end of the net would begin to flag downstream, and the crew would begin retrieval because the net was no longer fishing properly. Shorter drifts due to currents, snags, or other factors, potentially affected catches based on fish passage and encounter rate.

The main advantages to the fish wheel (with the video system) were that data could be collected 24 h per day, large quantities of fish could be counted in short amounts of time, and handling fish was eliminated (except when collecting ASL samples), which both increased efficiency and was more fish-friendly. However, there were several disadvantages:

1) To maintain optimal performance the fish wheel required large amounts of effort. Maintenance was often difficult, especially during periods of high debris and rapidly fluctuating water levels.
2) When debris loads were extremely high the fish wheel was inoperable. If the fish wheel was selected as the primary method for the right bank apportionment in the future, drift gillnets would need to be used as a backup during periods of high debris.
3) The video system was complex and required specialized technical experience for setup and maintenance. Species and sex determination were occasionally more difficult (and probably less accurate) with the video footage than when actually handling fish. Occasionally, minor issues with the video capture timing resulted in lost data; however, this was infrequent, and was an easy problem to fix.
4) In addition to the disadvantages, there were some potential sources of bias associated with the fish wheel. Smaller fish may have been able to pass through gaps in the fish lead more easily, or fell between the basket and video chutes more often. Different species or sizes of fish may have avoided the fish wheel at different rates.

In 2013, the fish wheel contractor recommended that a small gap nearshore of the fish lead panels be left open to allow for passing debris that had collected along the leads. This worked well but allowed fish traveling very close to shore to pass through. In 2014, a third small fish lead panel and seine net were added to close the gap. The seine net filled with debris quickly and was at times difficult to clean and redeploy, but it functioned adequately. In future seasons it would be beneficial to refine the nearshore fish lead system.

On a few occasions fish escaped out the livebox door when it was not secured properly, and in one instance fish were observed escaping out the top of the livebox. After these observations, special care was taken when closing the livebox door and a mesh cover was added to the top. On a few occasions debris stopped the fish wheel when nobody was present, which resulted in inaccurate CPUE calculations; however, the video system (with a record of when the last fish was caught) lessened this problem. The video counts had to be incorporated with the ASL counts, which created some problems with fishing start and stop times early on, but these issues were resolved with modified data sheets.

The test fishery was successful in several aspects. Fish were caught with all 6 mesh sizes in all 3 zones with the drift gillnets, and fish of varying sizes (from a least cisco to a Chinook salmon) were caught in the fish wheel. Fish were caught consistently throughout the season, although drift gillnet catches were occasionally low during periods of low passage. The species proportions of the fish wheel and right bank drift gillnets were similar (Table 8). The fish wheel and both the left and right bank drift gillnets covered a horizontal range in which the majority of fish were distributed on the sonar. These results were encouraging and support the likelihood that the test fishery was performing adequately.

Moving forward with the test fishery it would be beneficial to operate both right bank methods for another complete season to see if other issues arose that made one or the other more feasible. A quantitative analysis comparing the estimates generated by each method should also be performed, and if statistical differences exist, further assessment of these 2 methods would be necessary to determine which would provide a more representative sample of the species estimated by the sonar. In addition, a cost-benefit analysis should be performed to determine whether the larger sample size provided by the fish wheel outweighs the greater difficulties associated with maintenance. The drift gillnetting should be continued on the left bank in both the nearshore and offshore zones if conditions allow. With the numerous project components in 2013 and 2014, the crew workload was high. In future seasons it would be beneficial to have the fish wheel operated by a private contractor to allow more time for refinement of other project components and prevent crew burnout.

In the early stages of project planning it was proposed that if drift gillnetting was not possible on the left bank due to snags, the fish wheel catches could be used as a proxy if the species compositions were similar between banks and zones. The species proportions of the left bank nearshore, left bank offshore, and right bank nearshore zones turned out to be substantially different (Table 8); therefore, it would not be possible to use the fish wheel catches as a proxy for either of the left bank zones.

The estimates for all species in 2013 are considered incomplete for several reasons. Data collection started nearly a month later than the optimal start date of June 20 because of camp construction, and there were periods during which the sonar did not operate on 1 bank. The left bank test fishing did not begin until after the Chinook and summer chum runs had passed, and there was only usable left bank test fishing data from September. In addition, gillnet fishing was initially inconsistent, and both sonar and test fishing operations ended before the fall chum and coho salmon runs were fully complete, due to project budget constraints. However, comparisons of the run timing and total estimates to those from the Pilot Station sonar project for fall 2013, and the 2014 season were encouraging (Figures 27–29 and Table 17). In 2014, the Chinook and summer chum salmon run timing was early at the Pilot Station sonar project, with 50% of the Chinook salmon run passing the site on June 18, which was 8 days earlier than the mean date of June 26, and 50% of the summer chum salmon run passing the site on June 22, which was 6 days earlier than the mean date of June 28 (K. J. Schumann, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Due to the near-flood conditions early in the season at the Tanana River sonar project, the project began collecting data a week later than planned, and the early part of the Chinook and summer chum salmon runs may have been missed. In addition, data collection ended before the fall chum and coho salmon runs were fully complete, due to project budget constraints. However, because initial passage rates were low, and sonar and test fishery operations were mostly consistent, species estimates are considered nearly complete.

In general, smaller and more distinct pulses observed at the Pilot Station sonar project merged into larger pulses by the time the fish passed the Tanana River sonar project, probably due to variable swimming speeds over a long distance. In most cases the Tanana River sonar project estimates were greater than the Pilot Station sonar estimates (Table 17), which is the opposite of what would be expected, because harvest occurred between the 2 project locations. It is difficult to explain why because several factors affect the estimates, but more data collected in future seasons may help to gain a better understanding of the trend. Comparisons could not be made between the 2 projects for coho salmon, because a mixed stock analysis based on genetic sampling was not performed for this species at the Pilot Station sonar project.

The results of the nearshore detection study showed that the split-beam and DIDSON sonars produced very similar counts. Overall, the DIDSON counts were slightly higher than the split-beam counts, which may be a result of higher resolution on the DIDSON echograms, and the ability to use the DIDSON video. However, because the slope of the regression line was near 1, this suggests the split-beam sonar was adequately detecting nearshore targets. Based on this study it will not be necessary to deploy an additional imaging sonar to cover the nearshore region on the left bank.

The vertical distribution results indicated that on the right bank most fish were passing through the ensonified region of the water column. Little difference was observed in the distribution between the summer and fall seasons, but there did appear to be a slight difference during periods of high and low water. This behavior may be related to changes in water velocity. If possible, vertical distribution should be assessed on the left bank the following season.

The results from the fish behavior study at the sonar fish leads demonstrated that the fish leads directed fish into the ensonified range. Additionally, observations at the fish wheel leads indicated that the range covered by the fish wheel was adequate. It was not possible to accurately measure fish length in this study, but those swimming through the leads were probably smaller fish. In future seasons it would be beneficial to experiment with basket speed to assess avoidance behavior. Also, it would be advantageous to reduce the gaps in and between the lead panels, if possible, to minimize the number of fish swimming through. That few fish were observed encountering the lead panel nearest to shore suggests that fish passage through this nearshore region in 2013, before the third lead panel and seine net were added, was minimal.

Based on the information obtained during the 2013 and 2014 seasons, it would be feasible to use sonar in combination with drift gillnetting and a fish wheel to estimate salmon abundance in the Tanana River. In future seasons the primary goal would be to continue to refine species apportionment methods. Due to budget cuts in 2015, the Tanana River sonar project was discontinued and the remaining project funding was redirected to start a new feasibility project on the Kuskokwim River, where additional inseason management tools were needed. The camp on the Tanana River was fully dismantled in August 2015, and equipment was transferred to Bethel for the new Kuskokwim project.

ACKNOWLEDGEMENTS

The authors would like to thank the following organizations and individuals for their support: Manley Roadhouse and General Store, Manley Village Council, Dart Farm, and Gladys Dart, for provisions and staff support; Pam Redington and the Manley Park Association for extended use of campground facilities; Chuck Parker and the Manley Community Association for providing storage space for the fish wheel; Alaska Department of Transportation – Manley station for assisting with fish wheel deployment and removal; Joe Redington Jr. for use of his fish wheel site; Paul and Penny Breuer for providing equipment storage space and assisting with fish wheel removal; Teresa DeLima for providing parking space; Ryan Morrill for assisting with the initial site surveys; Dave and Lisa Daum for fish wheel video system construction and support; and Steve O'Brien and Ann Wood O'Brien for fish wheel construction, maintenance, advice, and staff support.

The authors would also like to thank the following people for their outstanding hard work and dedication to the project during the 2013 and 2014 seasons: crew leader Keegan Birchfield, and technicians Holly Carroll, Andrew George, Abraham Gioffre, Andrew Miller, Samantha Vranorsey, and Jayme Walden.

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TABLES AND FIGURES

Table 1.–Technical specifications for the HTI split-beam sonar at the Tanana River sonar project, 2014.

Component	Setting	Stratum	Value
Transducer	Beam size (h x w)		2.8° x 10°
Echosounder	Transmit power (dB)		20.0
	Receiver gain (dB)		-6.0
	Source level (dB)		216.5
	Through-system gain (dB)		-172.4
	Pulse width (ms)		0.4
	Blanking range (m)		2.0
	Time varied gain (TVG)		40 log(R)
	Ping rate (pps)	S1	14.0
		S2	7.0
		S3	4.5
	Range (m)	S1	50
		S2	100
		S3	150

Table 2.–Technical specifications for the ARIS sonar at the Tanana River sonar project, 2014.

Setting	Stratum	Value
Field of view (h x w)		14° x 28°
Frequency (MHz)		0.7
Transmit power (dB re 1 µPa at 1 m)		216.6
Receiver gain (dB)		20.0
Samples/beam		1024.0
Range start (m)		0.7
Frame rate (f/s)	S1	11.2
	S2	5.9
Range (m)	S1	20.3
	S2	40.1

Table 3.–List of major events with start and end dates at the Tanana River sonar project, 2013 and 2014.

	2013		2014	
Event	Start	End	Start	End
Camp setup	6/13	7/07	6/18	6/24
Left bank sonar operation	7/13	9/23	6/26	9/25
Right bank sonar operation	7/14	9/17	6/26	9/25
Fish wheel operation	7/16	9/23	7/11	9/23
Fish wheel video operation	ND	ND	7/23	9/23
Drift gillnet fishing	8/05	9/23	6/26	9/25
Set gillnet fishing	9/10	9/23	6/26	7/27
Camp breakdown	9/24	9/29	9/26	9/29

Note: In 2013, the left bank sonar did not operate on July 19 or August 20–27 and the right bank sonar did not operate July 21–30 or August 7–14. The fish wheel video system was not used during the 2013 season. The drift gillnets fished sporadically August 5–September 11 and consistently September 12–23. In 2014, the left bank sonar did not operate on June 29 and the right bank sonar did not operate on June 30. The fish wheel did not operate on August 4.

Table 4.–Range of lower and upper thresholds, in decibels, used in Echotastic for marking fish traces at the Tanana River sonar project, 2013 and 2014.

			Range	
Bank	Stratum	Threshold	2013	2014
Left	S1	Lower	-75 to -48	-75 to -45
		Upper	-36 to -16	-20 to -6
	S2	Lower	-75 to -53	-75 to -50
		Upper	-35 to -15	-24 to -6
	S3	Lower	-80 to -53	-75 to -52
		Upper	-35 to -23	-21 to -6
Right	S1	Lower	-53 to -15	-60 to -20
		Upper	-33 to 0	-20 to 0
	S2	Lower	-50 to -30	-60 to -23
		Upper	-33 to -5	-20 to 0

Table 5.–Drift gillnet schedule used for the second half of the 2014 season at the Tana River sonar project.

	Day			
Period	1[a]	2	3	4
1	2.75	4.00	2.75	4.00
	5.25	5.25	5.25	5.25
	6.50	6.50	6.50	6.50
	7.50	7.50	7.50	7.50
2	4.00	2.75	4.00	2.75
	5.25	5.25	5.25	5.25
	6.50	6.50	6.50	6.50
	7.50	7.50	7.50	7.50

[a] The test fishery crew continually rotated through each of the 4 days. For days 1 and 2 during fishing Period 1, and days 3 and 4 during fishing Period 2, the crew began fishing on the right bank. Otherwise, they began fishing on the left bank.

Table 6.–Total hours fished and percent of total time by method and mesh size at the Tanana River sonar project, 2013 and 2014.

		Hours		Percent	
Method	Mesh	2013	2014	2013	2014
Drift gillnets	2.50	0.2	0.0	1.1	0.0
	2.75	5.2	27.2	24.9	15.9
	4.00	1.8	28.6	8.5	16.7
	5.25	7.5	38.6	36.3	22.6
	6.50	6.0	38.9	29.1	22.8
	7.50	0.0	37.6	0.0	22.0
	Total	20.7	170.8	100.0	100.0
Set gillnets	2.75	14.0	43.2	21.9	24.6
	4.00	10.3	35.6	16.1	20.3
	5.25	25.7	32.0	40.3	18.2
	6.50	13.8	29.7	21.7	16.9
	7.50	0.0	35.2	0.0	20.0
	Total	63.8	175.8	100.0	100.0
Fish wheel	Total	624.9	990.8		

Table 7.–Fish caught in the Tanana River sonar test fishery, by zone, 2013 and 2014.

Year	Zone	Chinook	S chum	F chum	Coho	Other	Total
2013	1	0	0	357	33	2	392
	2	0	0	20	14	64	98
	3	0	0	92	62	38	192
	4	37	942	4,791	591	72	6,433
	Total	37	942	5,260	700	176	7,115
2014	1	16	358	703	186	38	1,301
	2	0	38	463	339	95	935
	3	22	231	93	67	4	417
	4	35	1,073	10,918	2,168	363	14,557
	Total	73	1,700	12,177	2,760	500	17,210

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). In 2013, the fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23; set gillnets fished September 10–23. Much of the Chinook and summer chum salmon runs were missed in the right bank and missed entirely in the left bank test fishery. Some of the late fall chum and coho salmon runs were missed as well. In 2014, the fish wheel operated July 11–September 23, but not on August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

Table 8.–Species proportions by zone at the Tanana River sonar project, 2013 and 2014.

Year	Zone	Chinook	S chum	F chum	Coho	Other
2013	1	0.000	0.000	0.911	0.084	0.005
	2	0.000	0.000	0.102	0.014	0.884
	3	0.000	0.000	0.660	0.155	0.185
	4	0.010	0.074	0.807	0.099	0.010
2014	1	0.037	0.353	0.462	0.091	0.057
	2	0.000	0.118	0.344	0.190	0.348
	3	0.091	0.738	0.128	0.032	0.011
	4	0.011	0.325	0.549	0.103	0.011

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). In 2013, the fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23; set gillnets fished September 10–23. Much of the Chinook and summer chum salmon runs were missed in the right bank and were missed entirely in the left bank test fishery. Some of the late fall chum and coho salmon runs were missed as well. In 2014, the fish wheel operated July 11–September 23, but not on August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

Table 9.–Number of fish caught and retained in the drift gillnets in the Tanana River sonar test fishery, 2013.

	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total	August	0	0	1	0	0	0	0	0	0	0	1
catch	September	0	0	448	95	13	11	0	0	16	0	583
	Total	0	0	449	95	13	11	0	0	16	0	584
Retained	August	0	0	0	0	0	0	0	0	0	0	0
fish	September	0	0	94	36	2	4	0	0	0	0	136
	Total	0	0	94	36	2	4	0	0	0	0	136
Proportion	August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
retained	September	0.00	0.00	0.21	0.38	0.15	0.36	0.00	0.00	0.00	0.00	0.23
	Total	0.00	0.00	0.21	0.38	0.15	0.36	0.00	0.00	0.00	0.00	0.23

Note: Drift gillnets fished sporadically August 5–September 11 and consistently September 12–23. The Chinook and summer chum salmon runs were missed entirely, and some of the late fall chum and coho salmon runs were missed as well. The whitefish catch included humpback whitefish and broad whitefish.

Table 10.–Number of fish caught and retained in the set gillnets in September in the Tanana River sonar test fishery, 2013.

	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total catch	0	0	20	14	20	20	0	17	0	7	98
Retained fish	0	0	6	5	4	3	0	0	0	0	18
Proportion retained	0.00	0.00	0.30	0.36	0.20	0.15	0.00	0.00	0.00	0.00	0.18

Note: Set gillnets fished September 10–23. The Chinook and summer chum salmon runs were missed entirely, and some of the late fall chum and coho salmon runs were missed as well. The whitefish catch included humpback whitefish and broad whitefish.

Table 11.–Number of fish caught and retained in the fish wheel on the right bank of the Tanana River, 2013.

	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total catch	July	36	675	0	0	5	6	0	0	0	0	722
	August	1	267	640	68	8	7	3	0	2	0	996
	September	0	0	4,151	523	18	19	4	0	0	0	4,715
	Total	37	942	4,791	591	31	32	7	0	2	0	6,433
Retained fish	July	0	1	0	0	0	1	0	0	0	0	2
	August	0	4	0	0	0	1	0	0	0	0	5
	September	0	0	5	2	1	3	3	0	0	0	14
	Total	0	5	5	2	1	5	3	0	0	0	21
Proportion retained	July	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
	August	0.00	0.01	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.01
	September	0.00	0.00	0.00	0.00	0.06	0.16	0.75	0.00	0.00	0.00	0.00
	Total	0.00	0.01	0.00	0.00	0.03	0.16	0.43	0.00	0.00	0.00	0.00

Note: The fish wheel operated July 16–September 23. Some of the Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The whitefish catch included humpback whitefish and broad whitefish.

Table 12.–Sex composition of salmon caught in the Tanana River sonar test fishery, by catch and percentage, 2013 and 2014.

Year	Sex	Chinook	S chum	F chum	Coho
2013	Male	13	420	2,599	477
	Female	12	498	2,647	221
	Unknown	12	24	14	2
	Total	37	942	5,260	700
	Male	35%	45%	49%	68%
	Female	32%	53%	50%	32%
	Unknown	32%	3%	0%	0%
2014	Male	37	894	6,525	1,694
	Female	36	805	5,652	1,066
	Unknown	0	1	0	0
	Total	73	1,700	12,177	2,760
	Male	51%	53%	54%	61%
	Female	49%	47%	46%	39%
	Unknown	0%	0%	0%	0%

Table 13.–Number of fish caught and retained in the drift gillnets in the Tanana River sonar test fishery, 2014.

	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total catch	June	17	3	0	0	0	0	0	0	0	0	20
	July	21	474	0	0	3	0	1	1	0	0	500
	August	0	130	204	37	9	11	1	1	10	0	403
	September	0	0	1,055	555	14	30	4	7	25	0	1,690
	Total	38	607	1,259	592	26	41	6	9	35	0	2,613
Retained fish	June	0	0	0	0	0	0	0	0	0	0	0
	July	0	12	0	0	2	0	1	1	0	0	16
	August	0	1	5	2	2	0	0	0	0	0	10
	September	0	0	42	31	1	0	0	0	0	0	74
	Total	0	13	47	33	5	0	1	1	0	0	100
Proportion retained	June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	July	0.00	0.03	0.00	0.00	0.67	0.00	1.00	1.00	0.00	0.00	0.03
	August	0.00	0.01	0.02	0.05	0.22	0.00	0.00	0.00	0.00	0.00	0.02
	September	0.00	0.00	0.04	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.04
	Total	0.00	0.02	0.04	0.06	0.19	0.00	0.17	0.11	0.00	0.00	0.04

Note: Drift gillnets fished June 26–September 25. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The whitefish catch included humpback whitefish and broad whitefish.

Table 14.–Number of fish caught and retained in the set gillnets in the Tanana River sonar test fishery, 2014.

	Month		Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total	June		0	0	0	0	0	1	0	0	0	1	2
catch	July		0	20	0	0	0	8	1	0	6	3	38
		Total	0	20	0	0	0	9	1	0	6	4	40
Retained	June		0	0	0	0	0	0	0	0	0	1	1
fish	July		0	2	0	0	0	0	1	0	0	0	3
		Total	0	2	0	0	0	0	1	0	0	1	4
Proportion	June		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
retained	July		0.00	0.10	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.08
		Total	0.00	0.10	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.10

Note: Drift gillnets fished June 26–September 25. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The whitefish catch included humpback whitefish and broad whitefish.

Table 15.–Number of fish caught and retained in the fish wheel on the right bank of the Tanana River, 2014.

	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
Total catch	July	34	873	0	0	2	2	4	0	0	0	915
	August	1	200	1,026	235	43	35	5	1	2	0	1,548
	September	0	0	9,892	1,933	153	106	5	1	4	0	12,094
	Total	35	1,073	10,918	2,168	198	143	14	2	6	0	14,557
Retained fish	July	0	2	0	0	0	0	0	0	0	0	2
	August	0	2	2	0	2	0	0	1	0	0	7
	September	0	0	7	0	3	7	0	0	0	0	17
	Total	0	4	9	0	5	7	0	1	0	0	26
Proportion retained	July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	August	0.00	0.01	0.00	0.00	0.05	0.00	0.00	1.00	0.00	0.00	0.00
	September	0.00	0.00	0.00	0.00	0.02	0.07	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.03	0.05	0.00	0.50	0.00	0.00	0.00

Note: The fish wheel operated July 11–September 23, but not on August 4. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The whitefish catch included humpback whitefish and broad whitefish.

Table 16.–Age composition of Chinook salmon caught in the Tanana River sonar test fishery, 2014.

Age	N	Proportion
1.1	3	0.044
1.2	7	0.103
1.3	43	0.632
1.4	12	0.176
2.4	1	0.015
Unreadable	2	0.029
Total	68	1.000

Table 17.–Tanana River sonar estimates, and Pilot Station sonar project mixed stock analysis estimates with 90% confidence intervals (CI).

		Tanana River sonar project			Pilot Station mixed stock analysis		
			90% CI			90% CI	
Year	Species	Estimate	Lower	Upper	Estimate	Lower	Upper
2013	F chum	265,989	251,979	279,999	252,732	222,878	282,586
2014	Chinook	15,502	12,701	18,303	22,718	14,753	30,682
	S chum	165,526	161,756	169,296	114,208	78,299	150,116
	F chum	222,627	217,375	227,879	196,405	171,990	220,820
	Total chum	388,153	381,687	394,619	310,613	266,105	355,120

Note: Pilot Station mixed stock analysis estimates for summer and fall chum were calculated using cumulative season proportions. Goodman's method was used to calculate the combined variance for the sonar and mixed stock analysis estimates from Pilot Station (Goodman 1960). In 2013, at the Tanana River sonar project, the left bank sonar operated July 13–September 23, but not on July 19 or August 20–27. The right bank sonar operated July 14–September 17, but not July 21–30 or August 7–14. The fish wheel operated July 16–September 23; drift gillnets were fished sporadically August 5–September 11, and consistently September 12–23; and set gillnets fished September 10–23. In 2014, the left and right bank sonars operated June 26–September 25, but the left bank sonar did not operate on June 29 and the right bank sonar did not operate on June 30. The fish wheel operated July 11–September 23, but not on August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates for all species from 2013 are considered incomplete but estimates from 2014 are considered nearly complete.

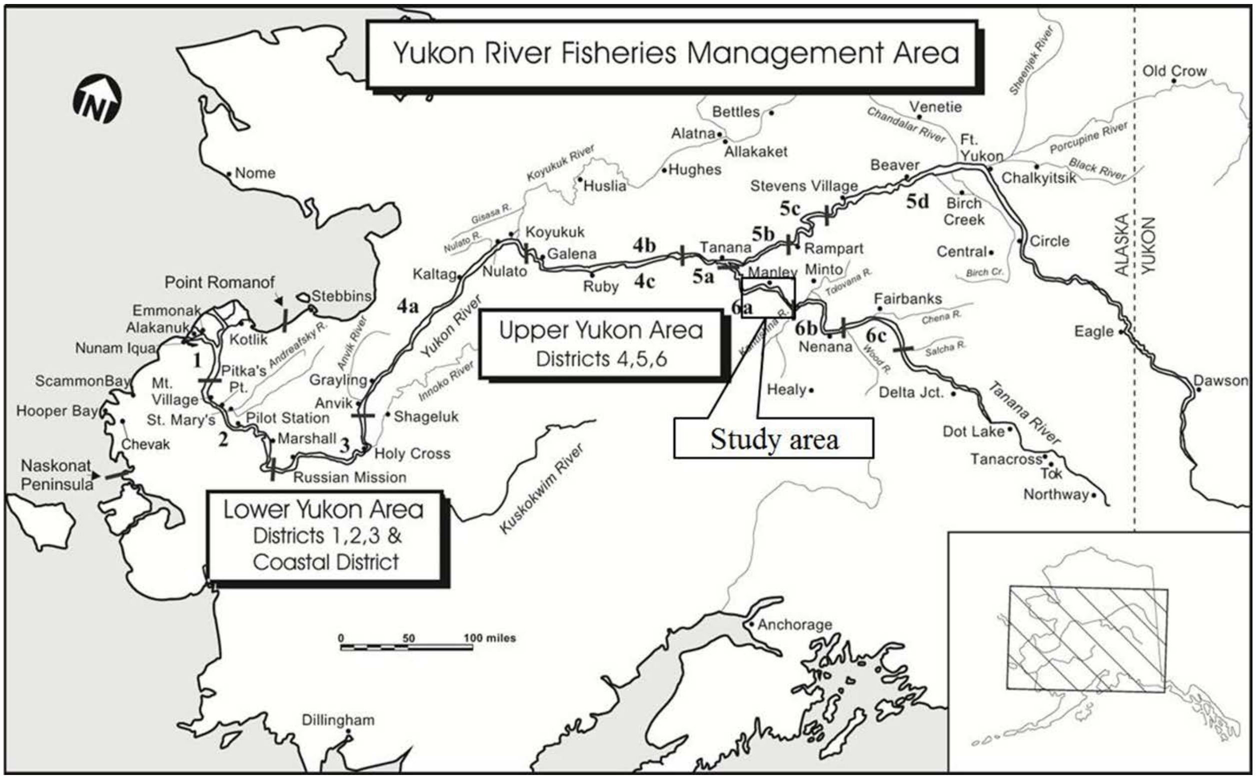


Figure 1.–Fishing districts and communities of the Yukon River watershed.

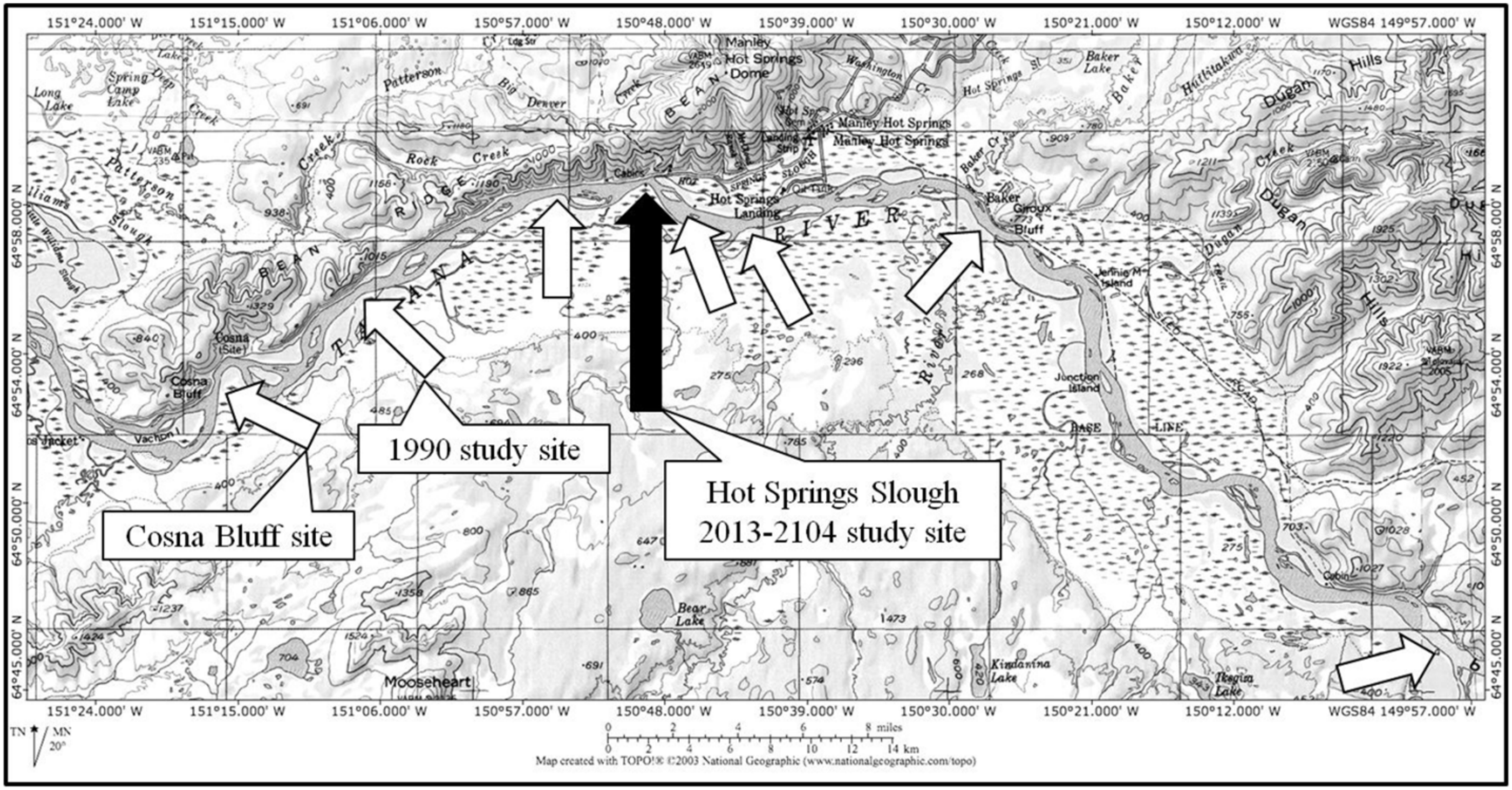


Figure 2.–Sites surveyed during the initial investigation on the Tanana River, 2012.

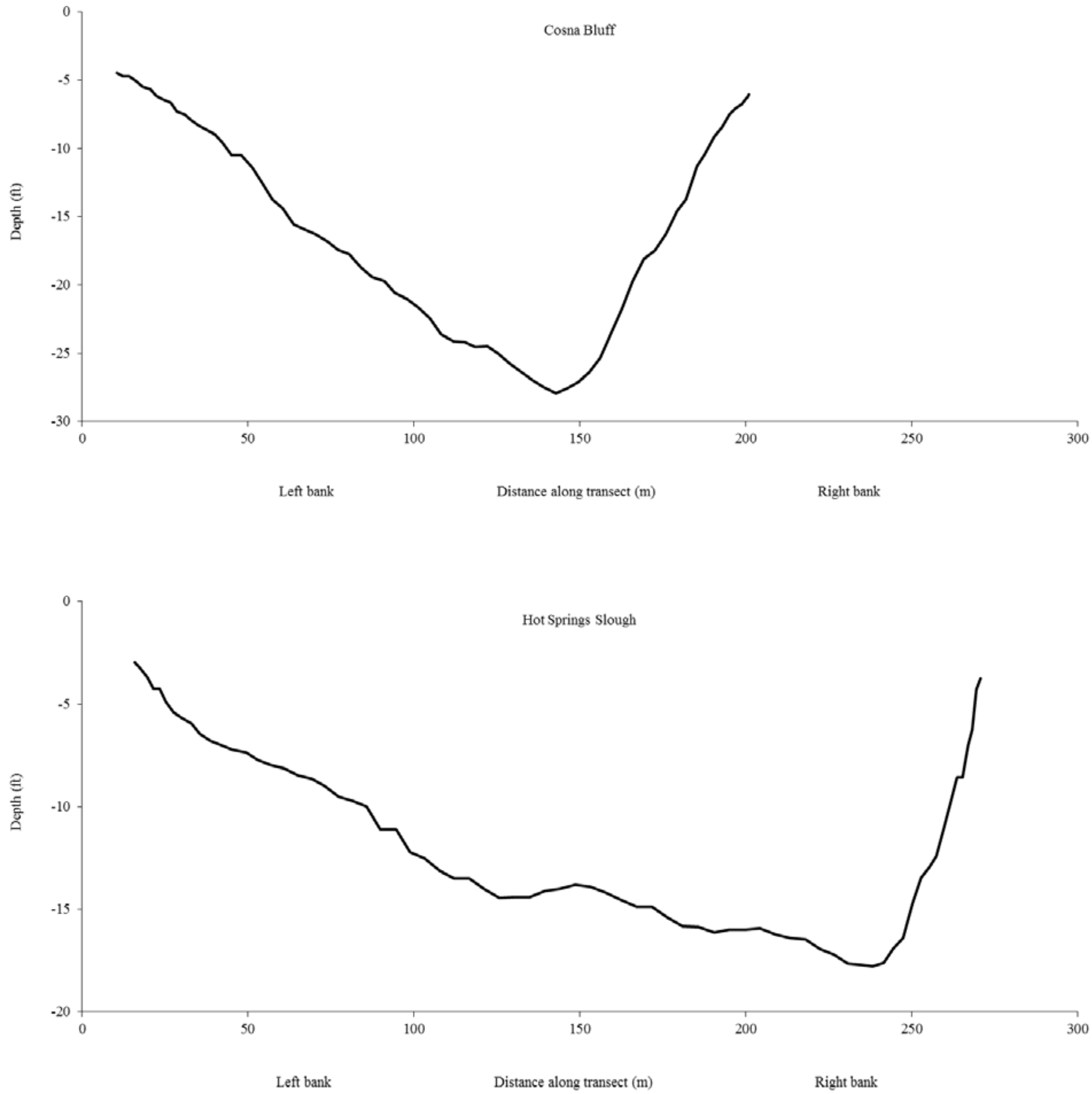


Figure 3.–Bottom profiles, looking downstream, at the Cosna Bluff and Hot Springs Slough sites on the Tanana River, 2012.

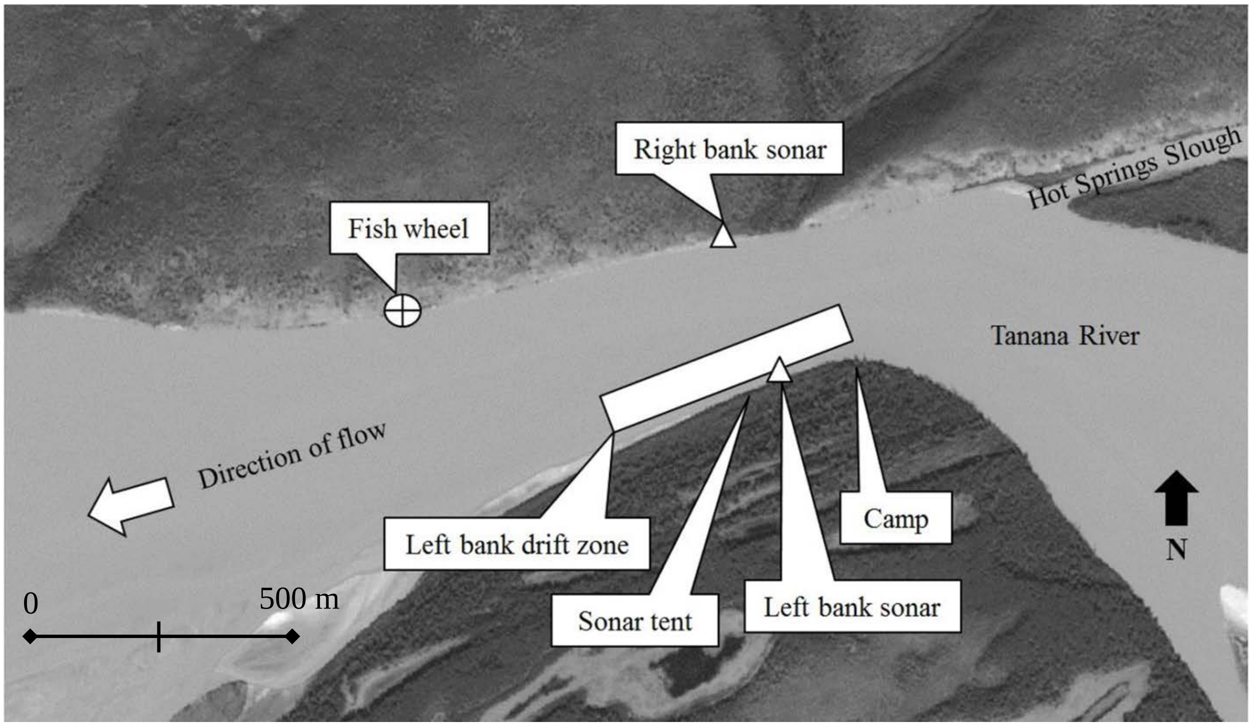


Figure 4.–Tanana River sonar project site, showing general sonar locations and upriver test fishery areas.

Figure 5.–HTI split-beam transducer mounted to 662H rotators attached to aluminum pod at the Tanana River sonar project.

Figure 6.–ARIS sonar mounted to AR2 rotator attached to aluminum pod at the Tanana River sonar project.

Figure 7.–Fish lead used to direct fish offshore into the ensonified region on the left bank at the Tanana River sonar project.

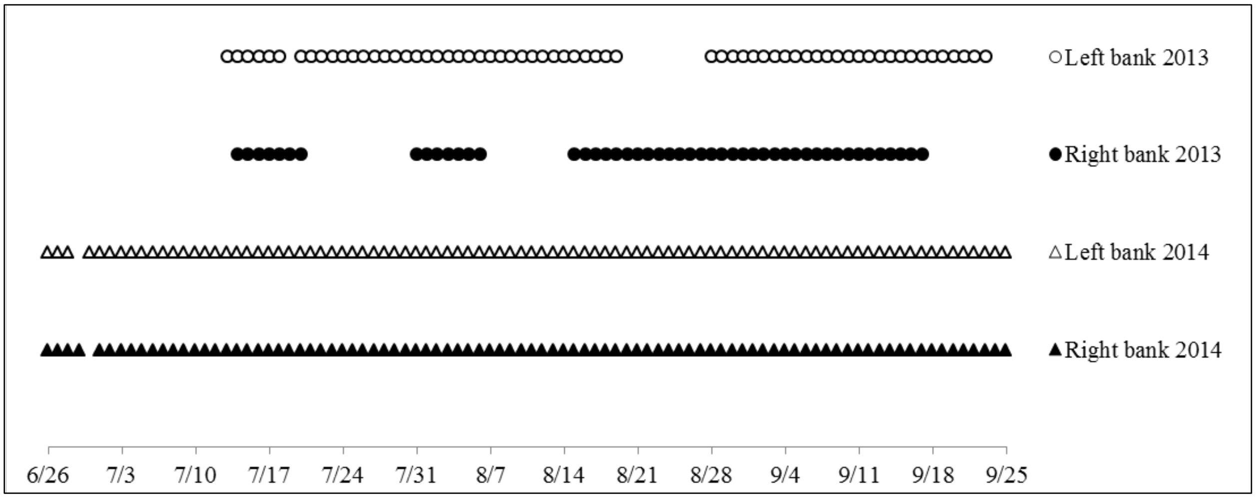


Figure 8.–Dates of sonar operation at the Tanana River sonar project, 2013 and 2014.

Figure 9.–Debris on the beach along the left bank of the Hot Springs Slough site on the Tanana River, 2012.

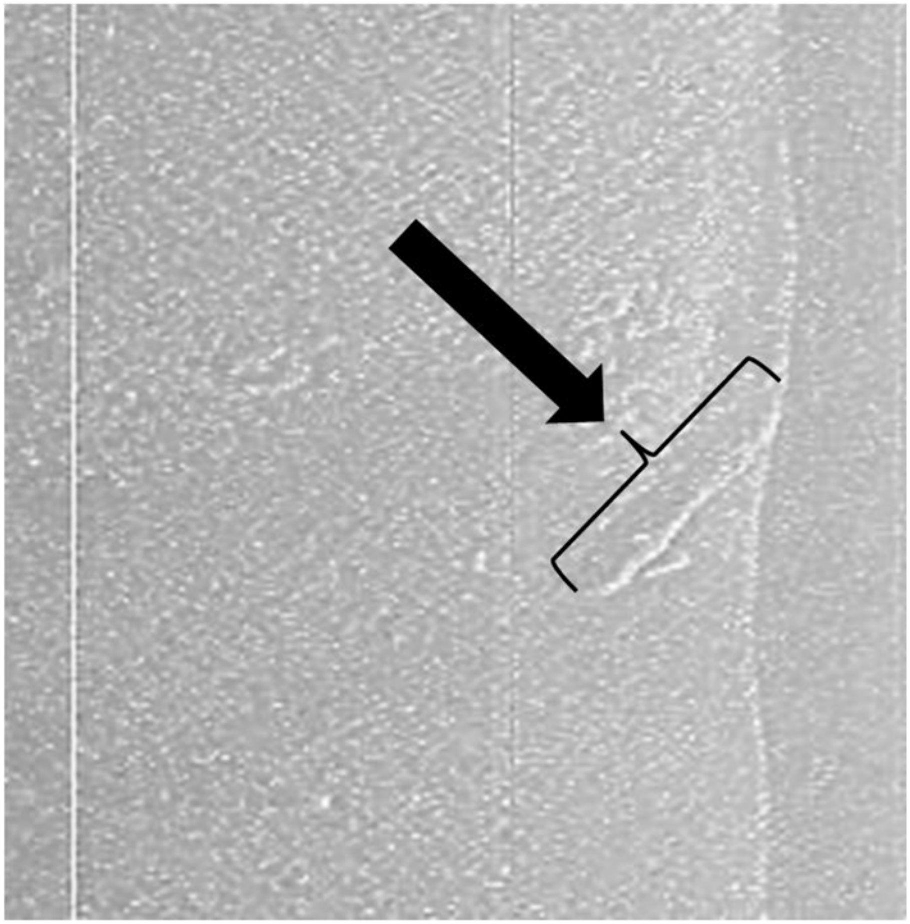


Figure 10.–Submerged debris observed using the side-scan sonar on the left bank at the Hot Springs Slough site on the Tanana River, 2012.

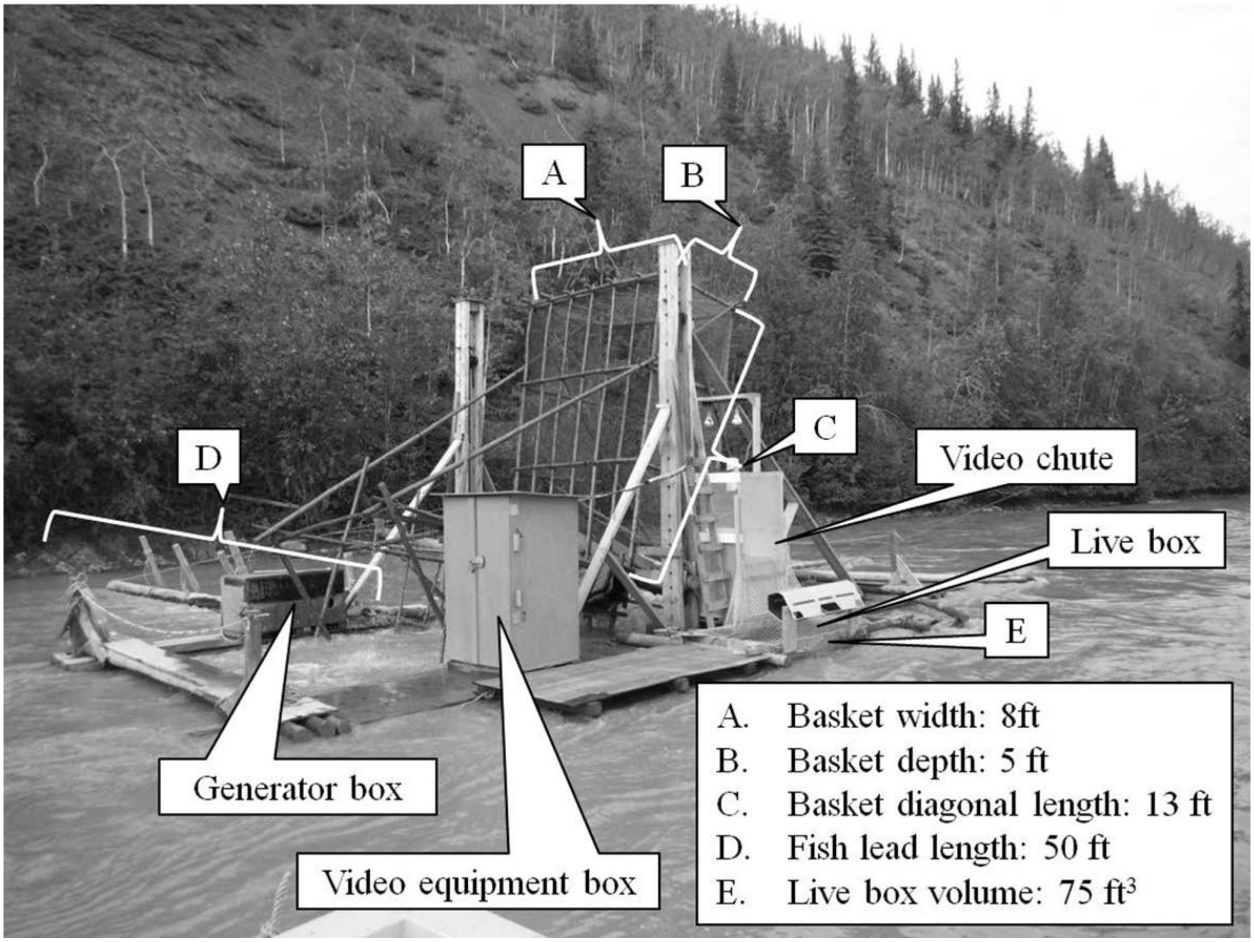


Figure 11.–Dimensions of the fish wheel used at the Tanana River sonar project.

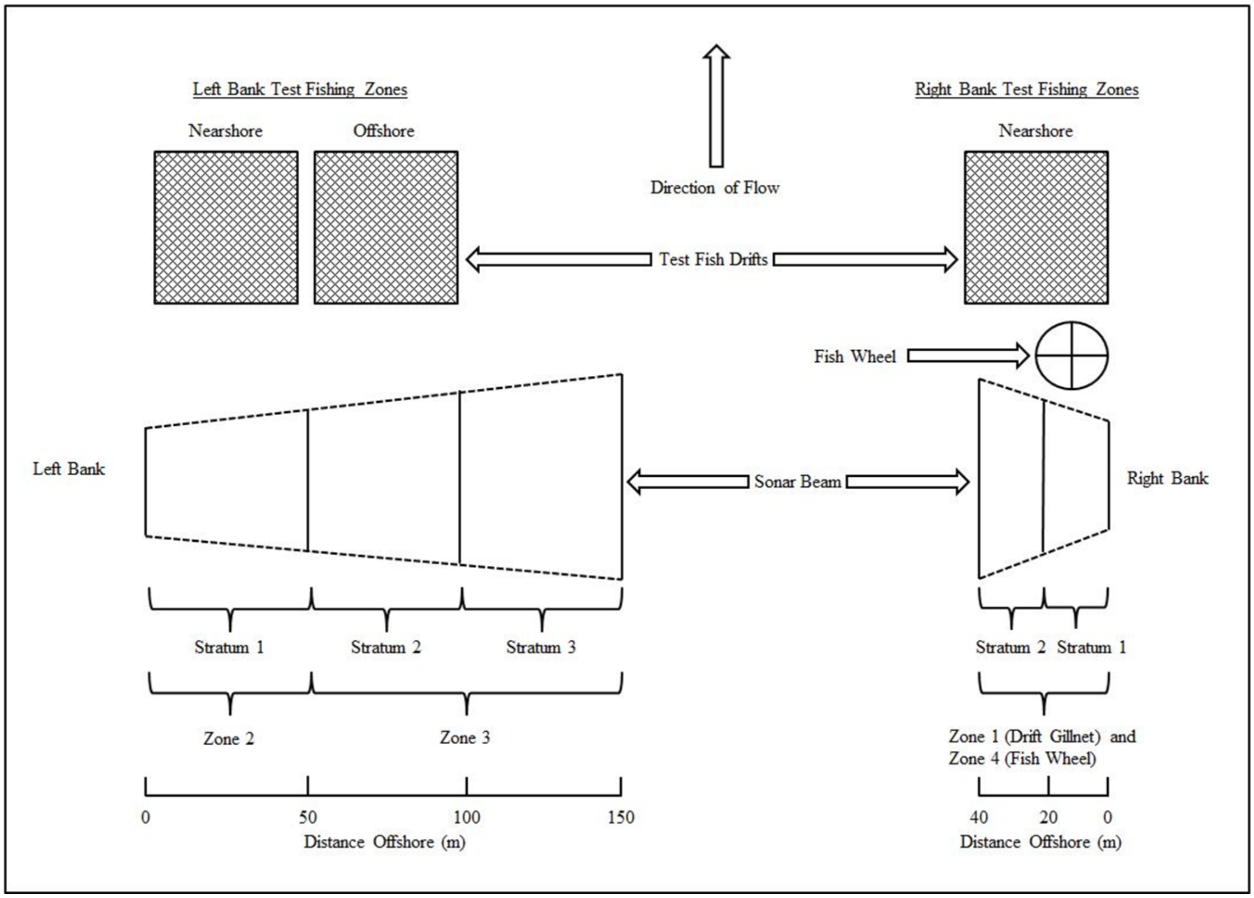


Figure 12.–Illustration of the relationship between sonar strata and test fishing zones at the Tanana River sonar project.

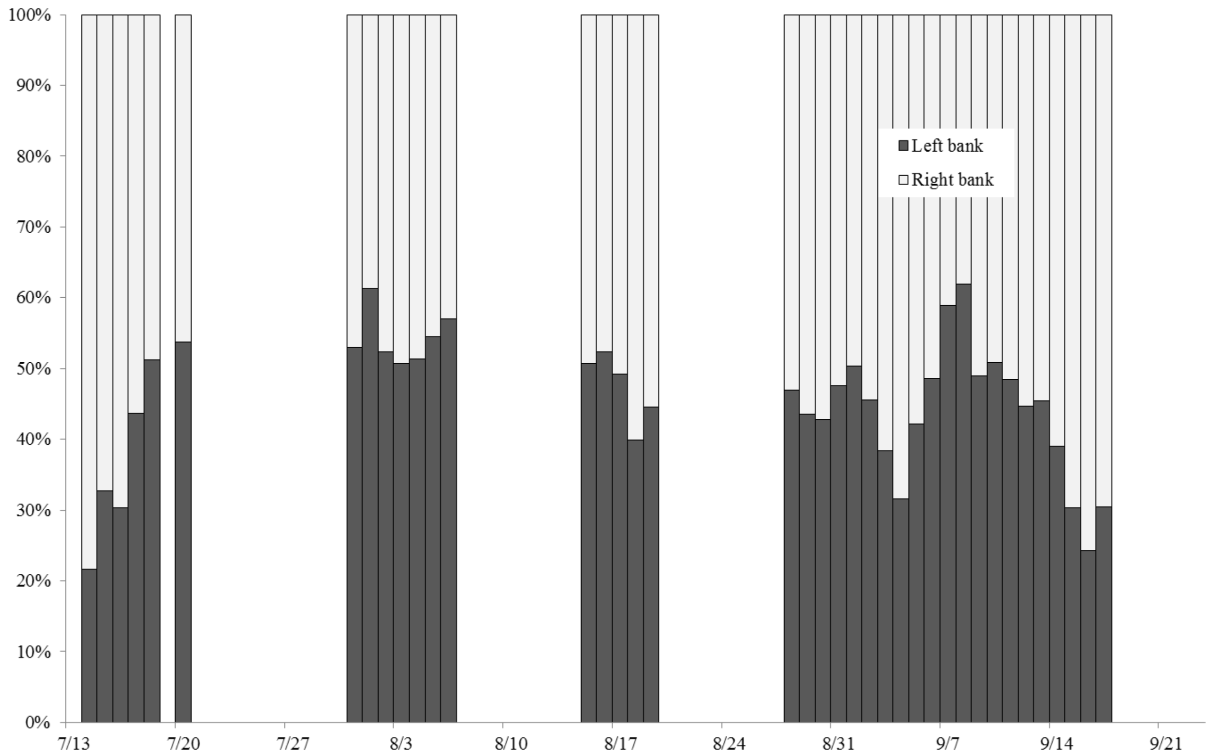
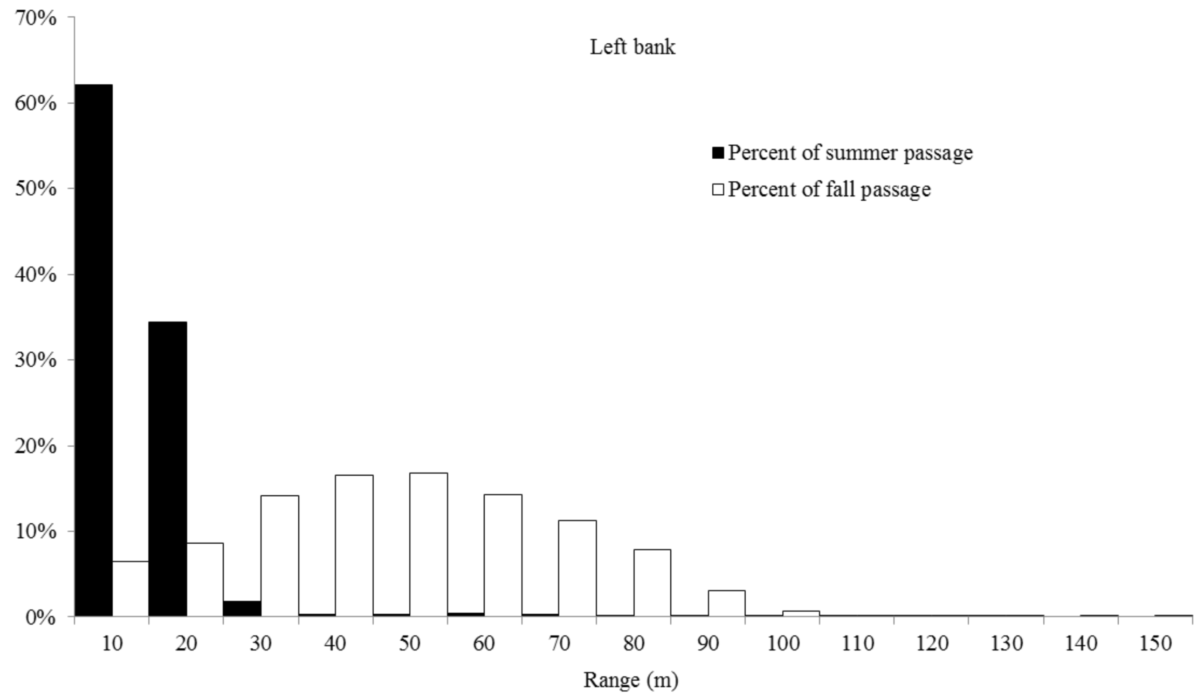


Figure 13.–Proportion of daily sonar estimates by bank at the Tanana River sonar project, 2013.

Note: Blank areas represent days when at least 1 of the sonars was not operational.



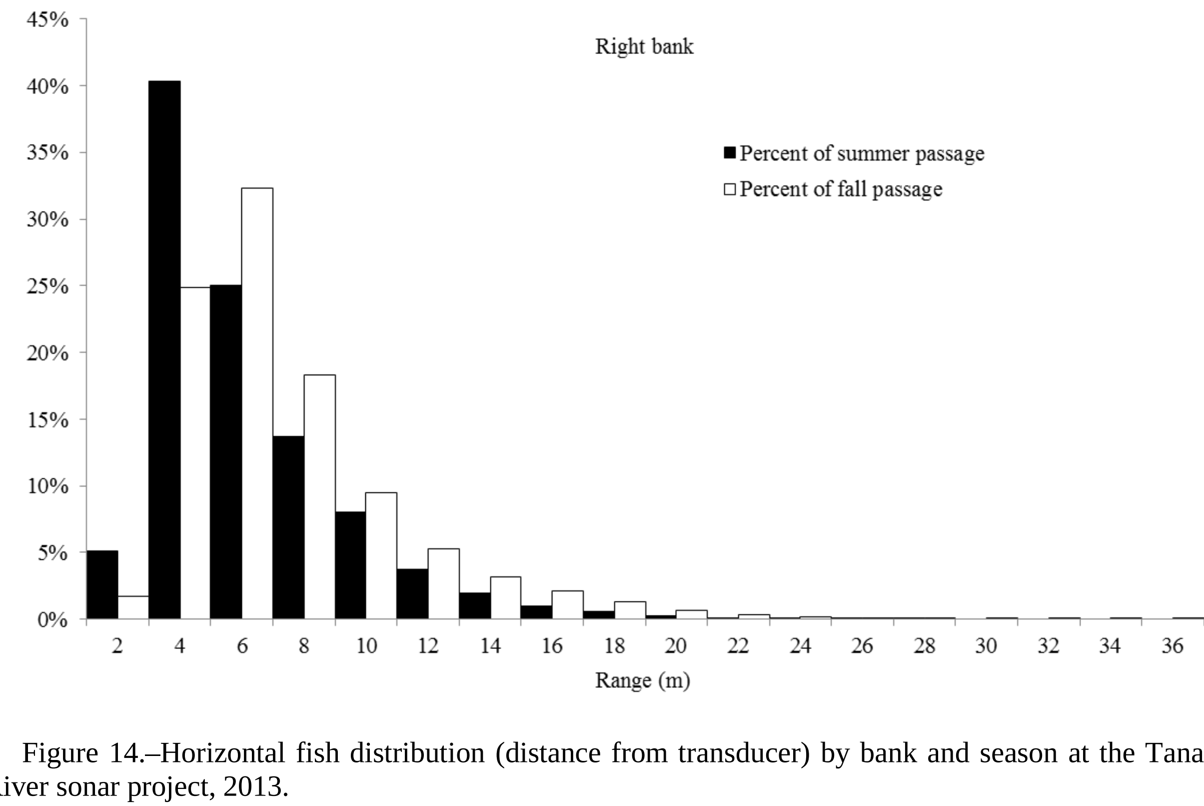


Figure 14.–Horizontal fish distribution (distance from transducer) by bank and season at the Tanana River sonar project, 2013.

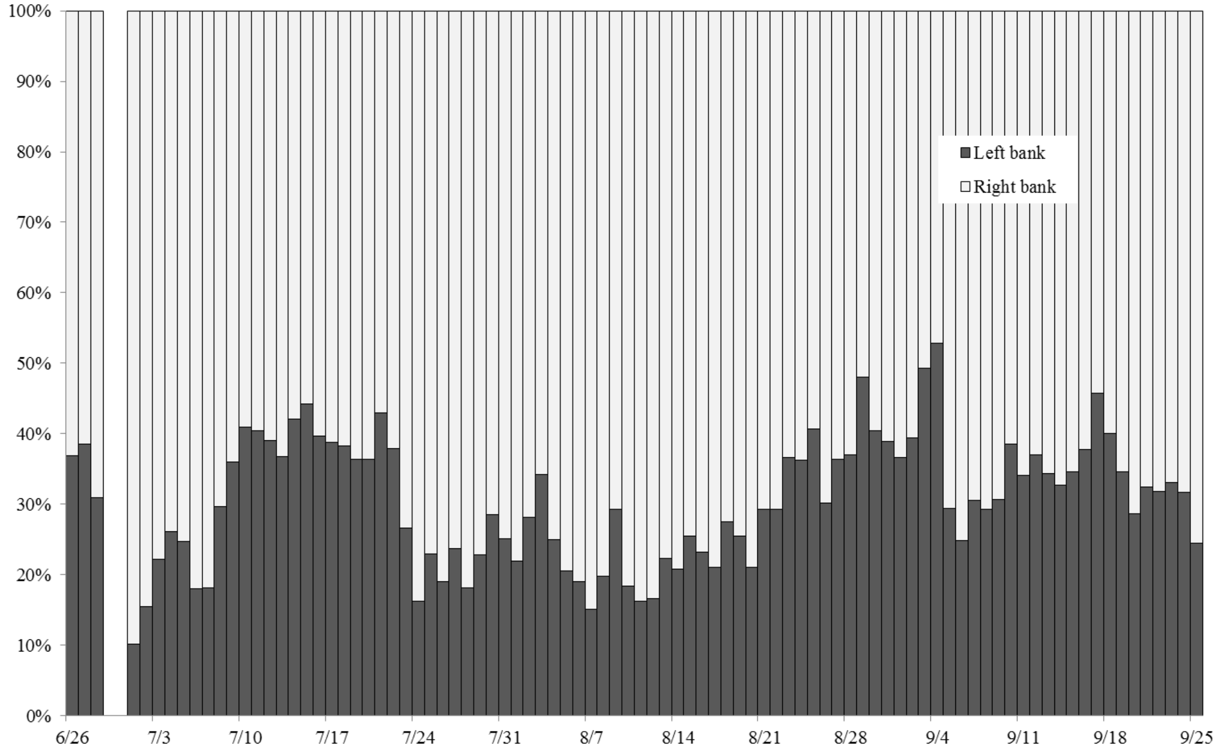
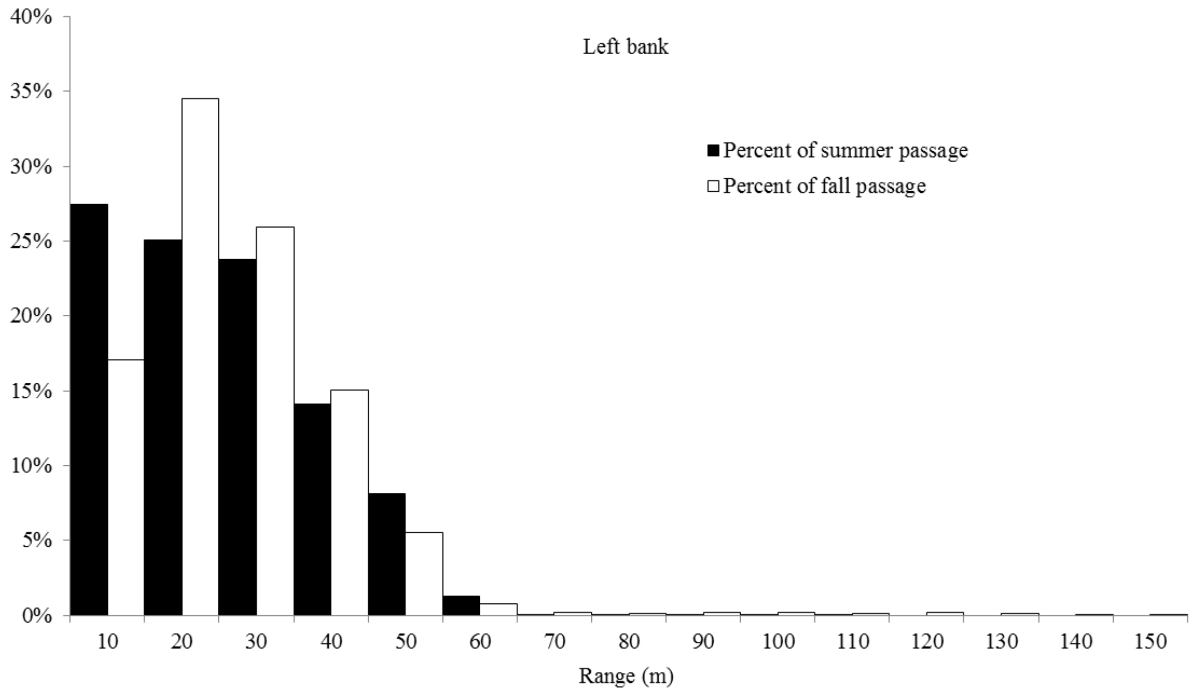


Figure 15.–Proportion of daily sonar estimates by bank at the Tanana River sonar project, 2014.

Note: Blank areas represent days when at least 1 of the sonars was not operational.



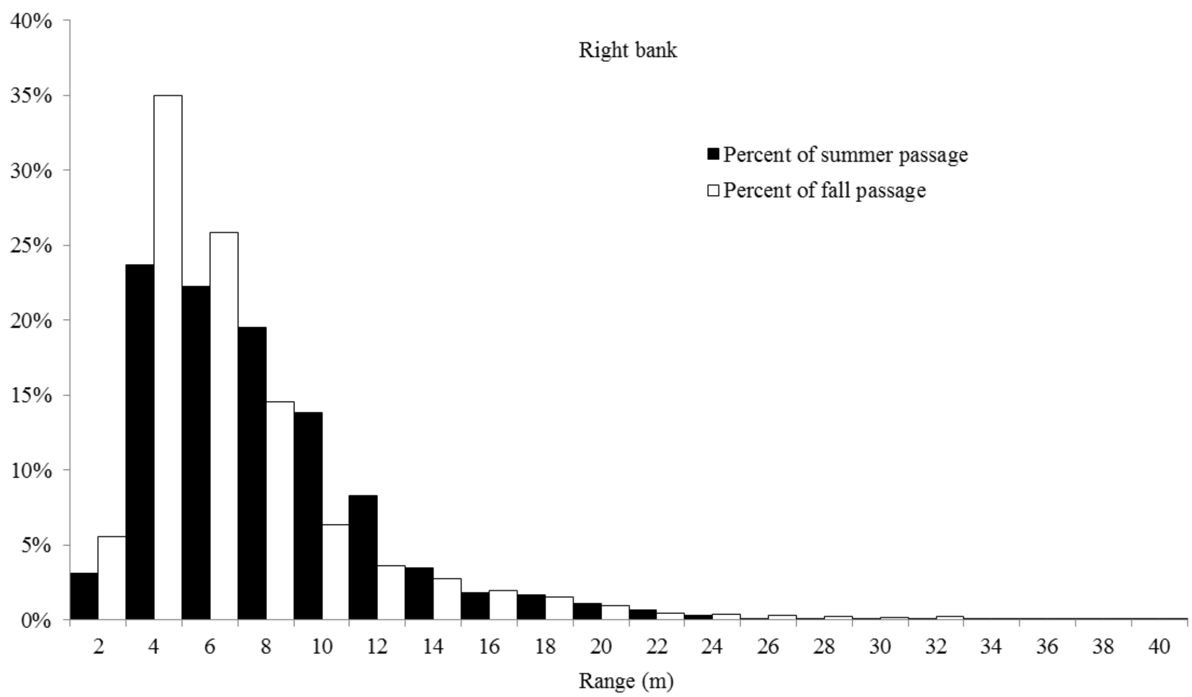


Figure 16.–Horizontal fish distribution (distance from transducer) by bank and season at the Tanana River sonar project, 2014.

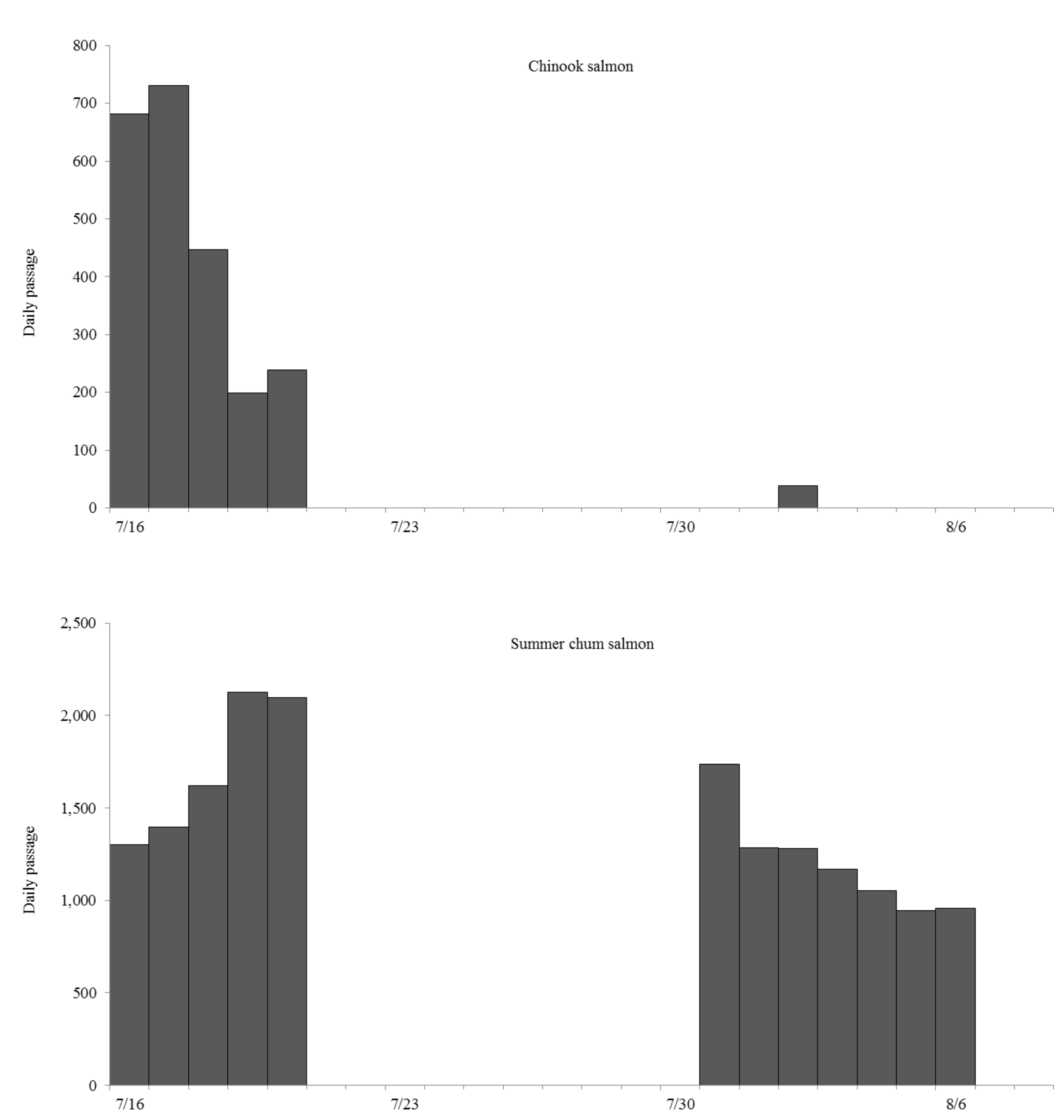


Figure 17.–Chinook and summer chum salmon daily right bank passage estimates at the Tanana River sonar project, 2013.

Note: The right bank sonar did not operate July 21–30 and August 7–14. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11, and consistently September 12–23; and set gillnets fished September 10–23. There were no Chinook and summer chum estimates on the left bank, and right bank estimates are considered incomplete.

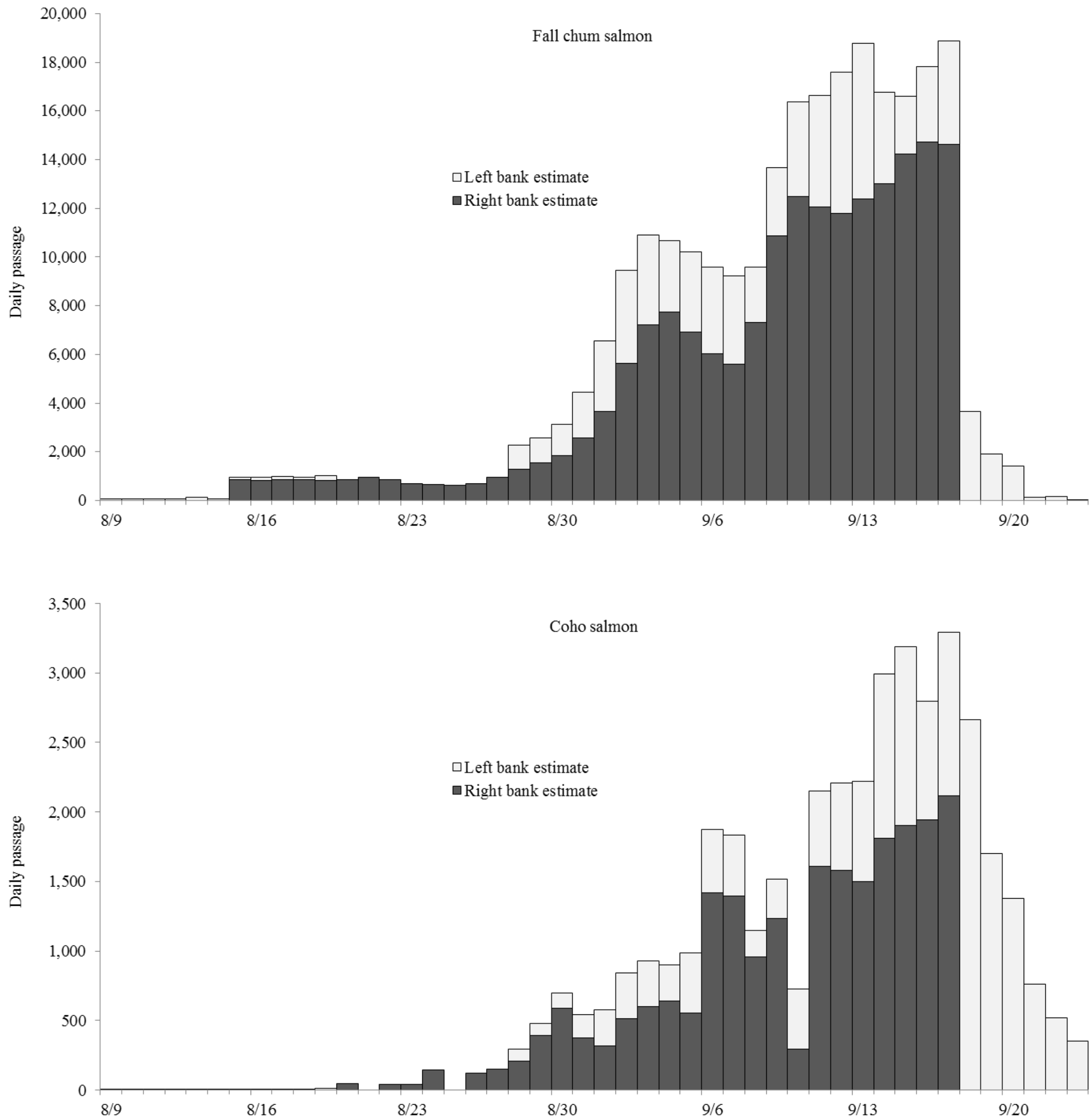


Figure 18.–Fall chum and coho salmon daily passage estimates at the Tanana River sonar project, 2013.

Note: The left bank sonar did not operate August 20–27, and the right bank sonar did not operate August 7–14 and September 18–23. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11, and consistently September 12–23; and set gillnets fished September 10–23. Estimates are considered incomplete.

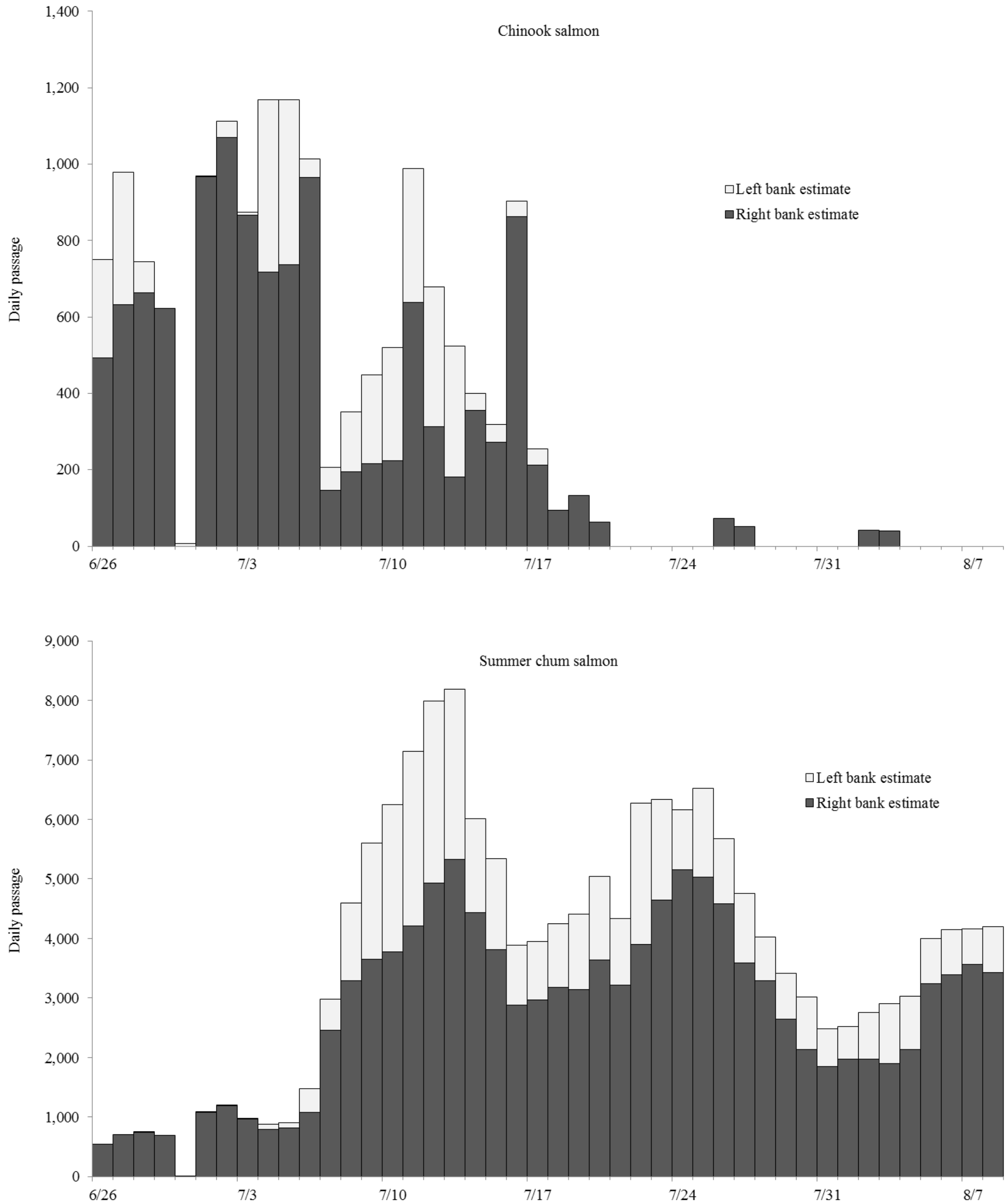


Figure 19.–Chinook and summer chum salmon daily passage estimates at the Tanana River sonar project, 2014.

Note: The left bank sonar did not operate June 29, and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete.

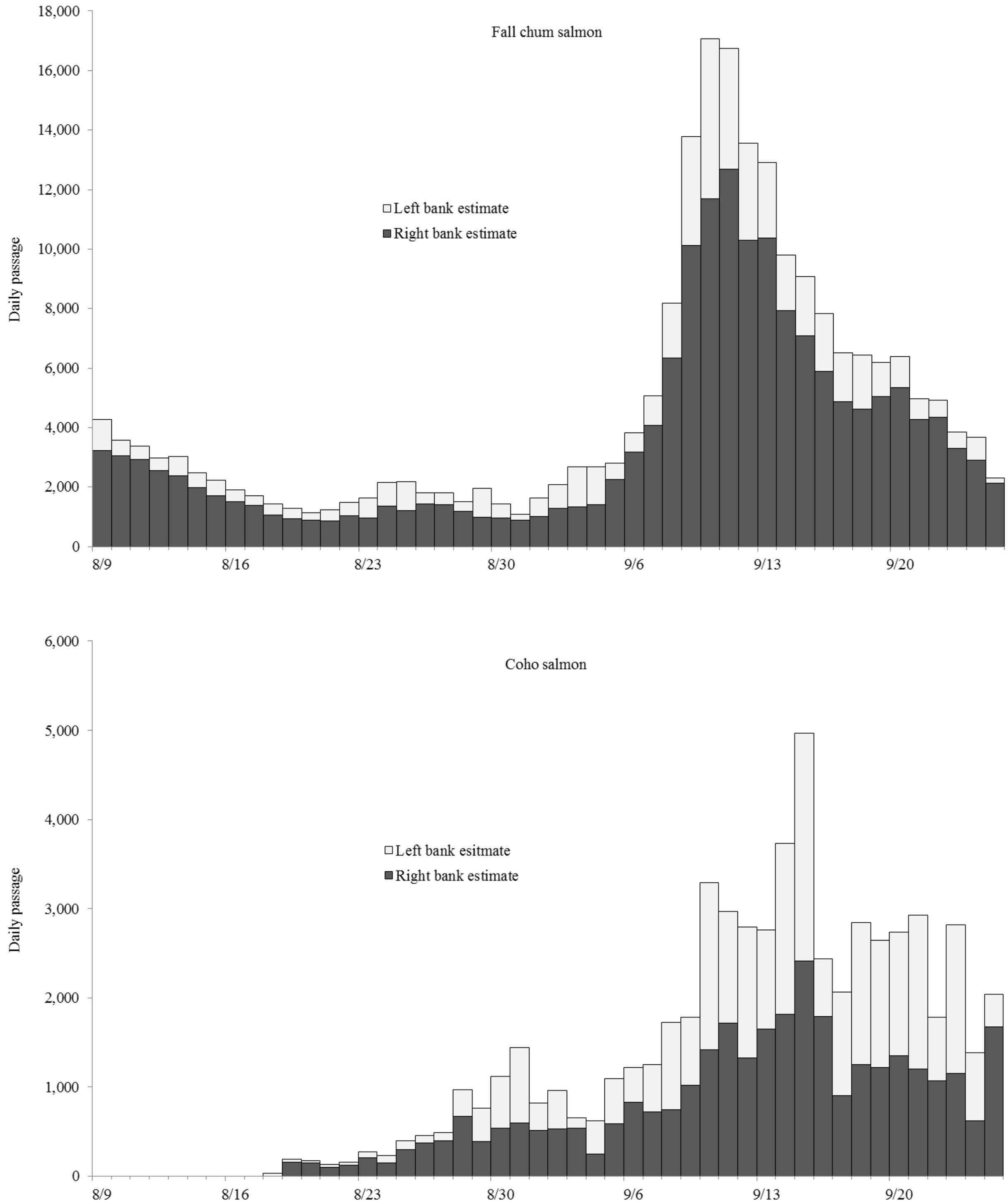


Figure 20.–Fall chum and coho salmon daily passage estimates at the Tanana River sonar project, 2014.

Note: The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete.

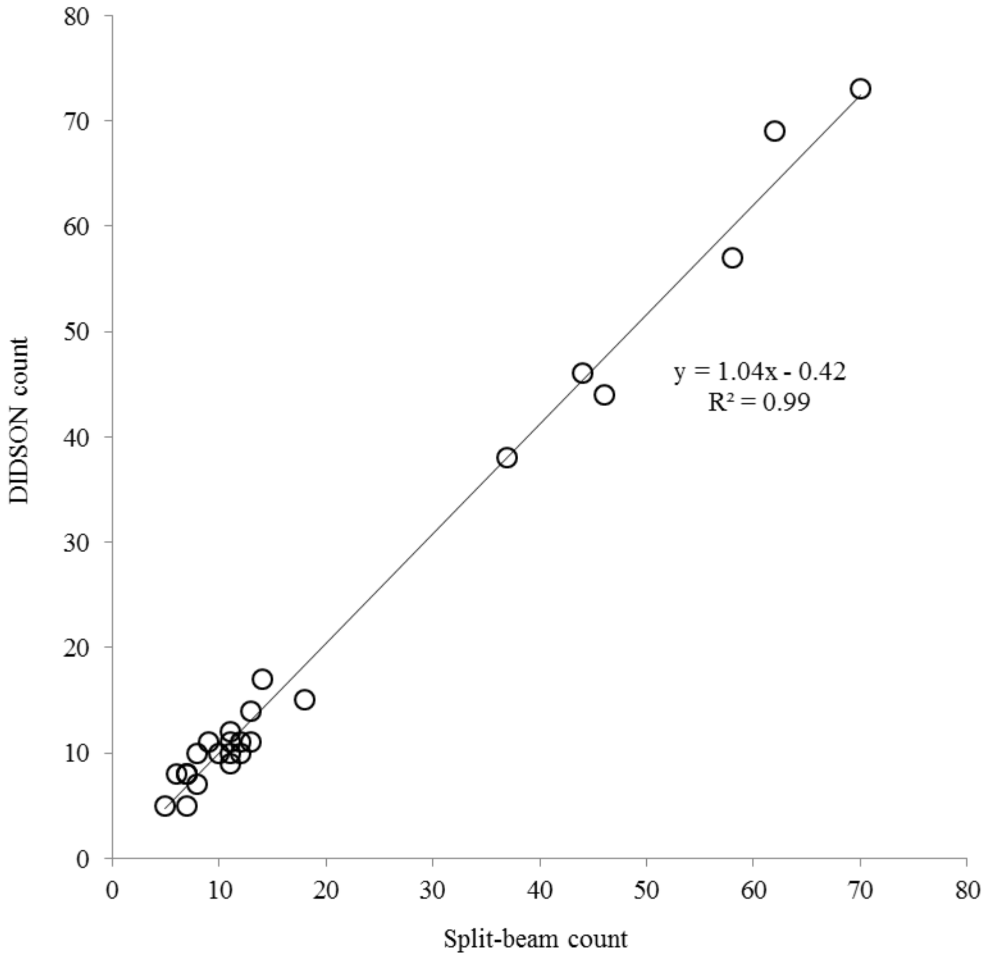


Figure 21.–Relationship between split-beam and DIDSON sonar counts, within the range of 0–40 m, when the sonars were operated side-by-side on the left bank at the Tanana River sonar project, 2014.

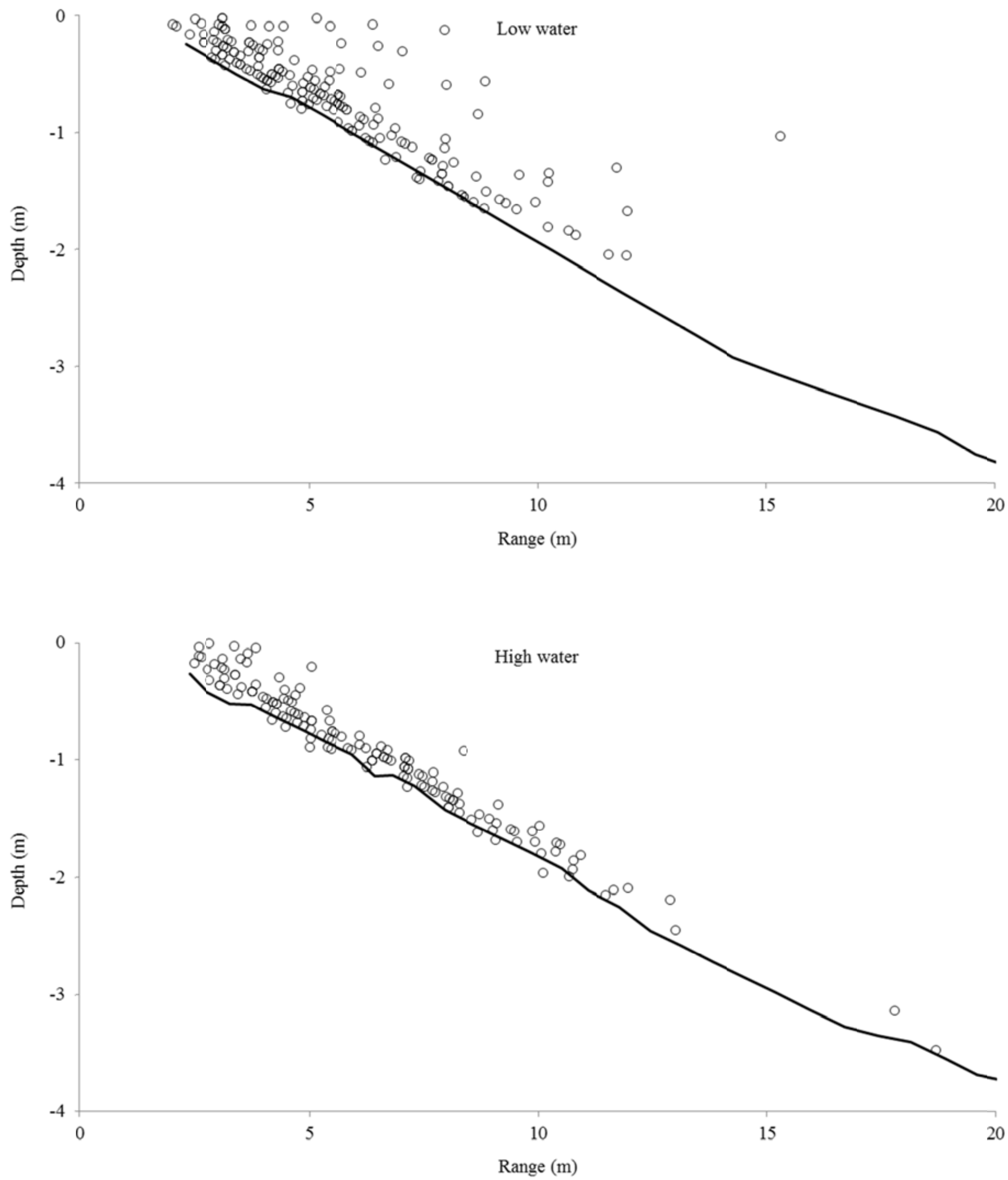


Figure 22.–Vertical and horizontal distribution of sonar targets on the right bank during the summer season for low water (top) and high water (bottom) at the Tanana River sonar project, 2014.

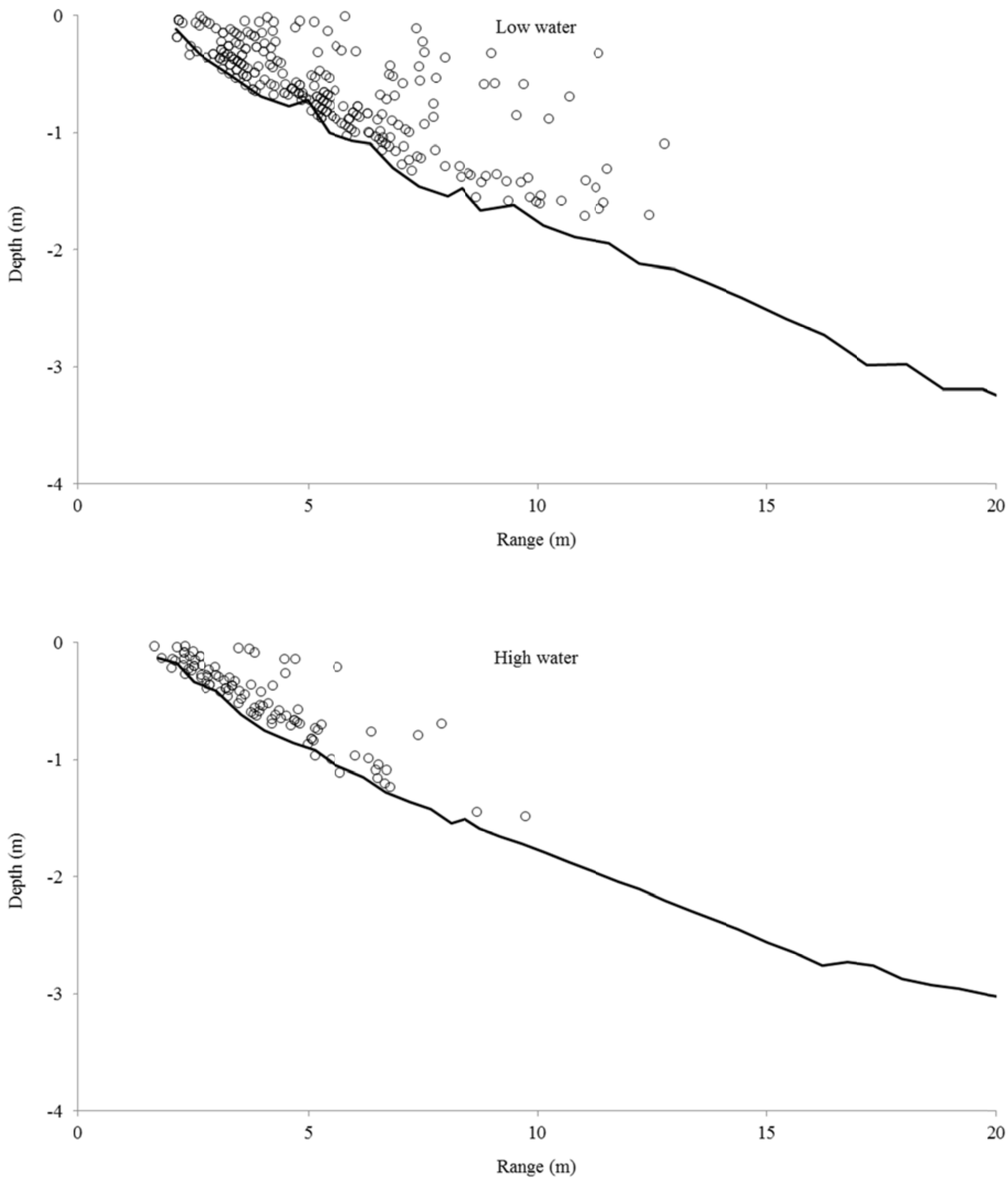


Figure 23.–Vertical and horizontal distribution of sonar targets on the right bank during the fall season for low water (top) and high water (bottom) at the Tanana River sonar project, 2014.

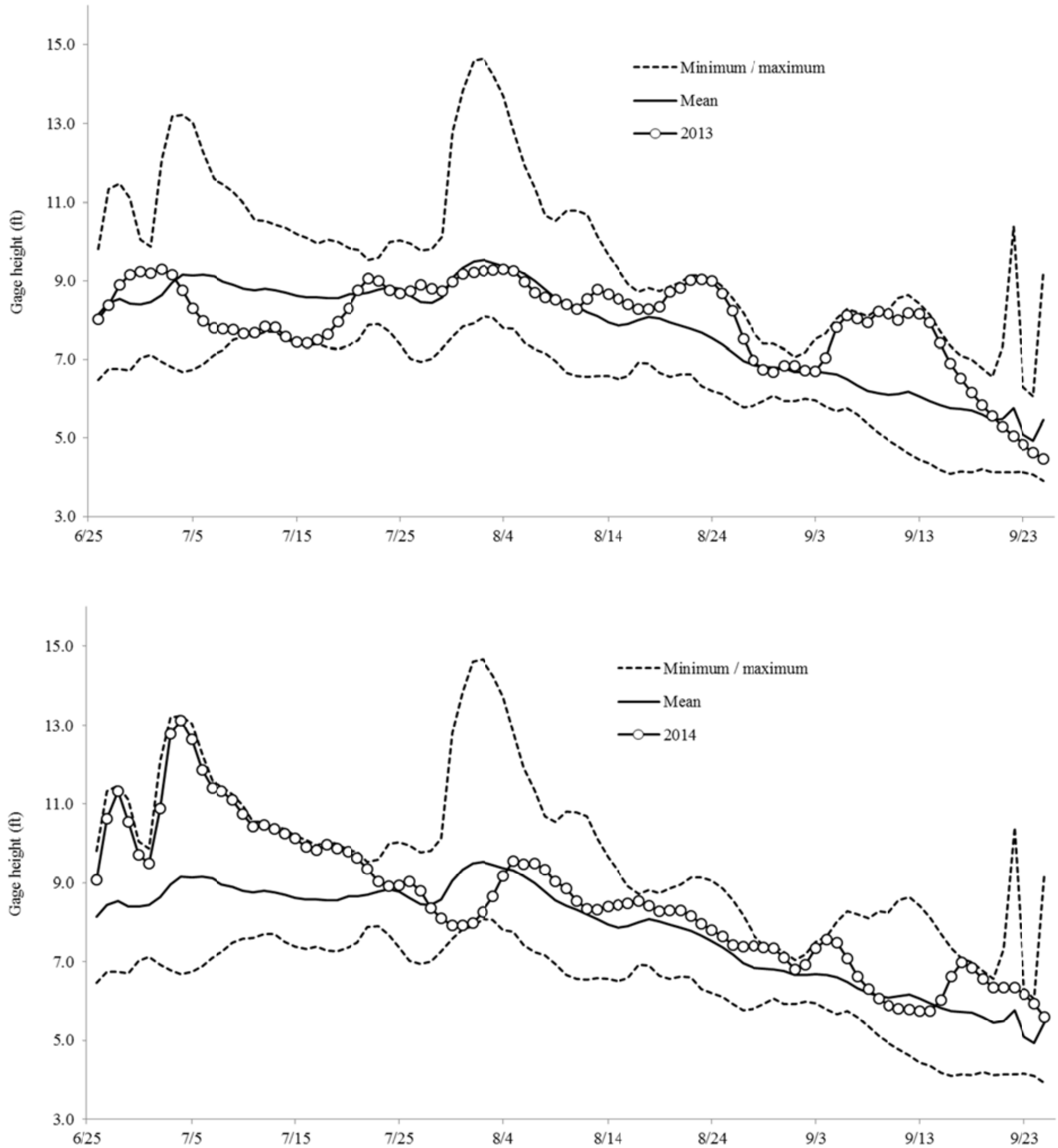


Figure 24.–Tanana River daily water level during the 2013 and 2014 seasons compared to the minimum, maximum, and mean gage height, 2007–2014.

Source: United States Geological Service, Nenana gaging station, located 163 km upriver from the sonar site.

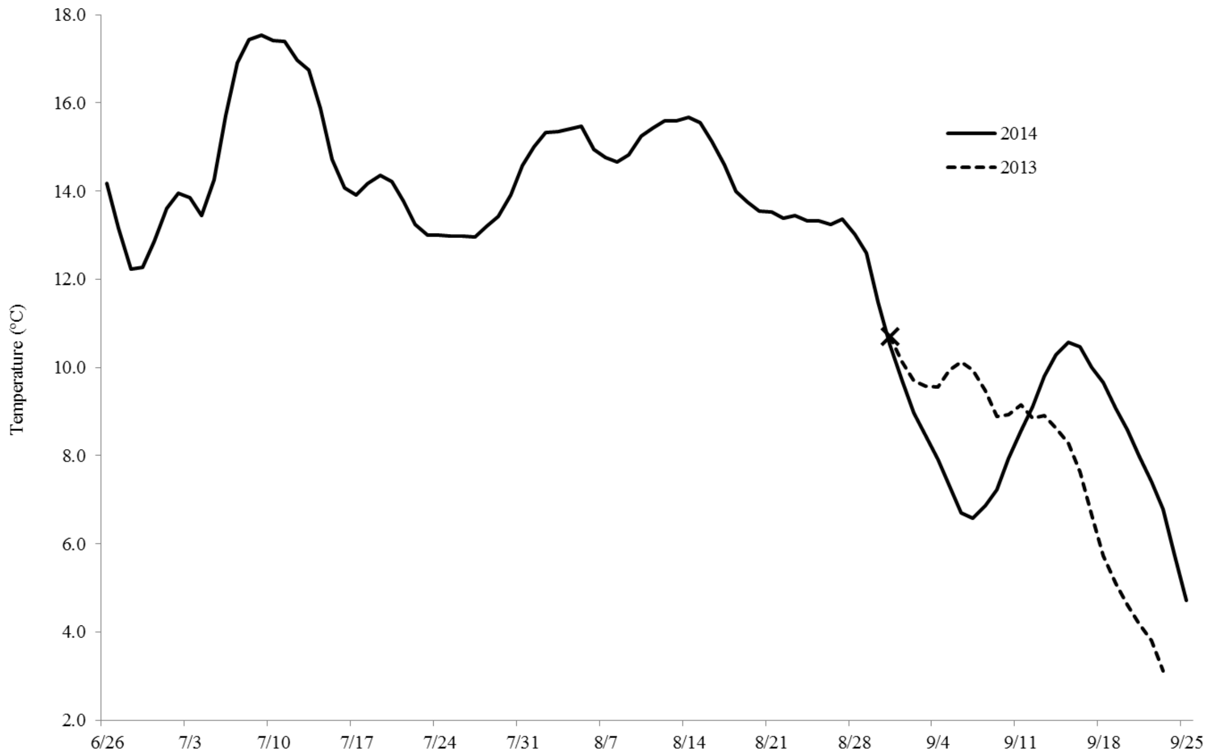


Figure 25.–Mean daily water temperatures recorded on the left bank with an Onset HOBO Water Temperature Pro v2 data logger at the Tanana River sonar project, 2013 and 2014.

Note: Data collection began on August 31 in 2013. The temperatures recorded on the right bank were very similar to those on the left bank.

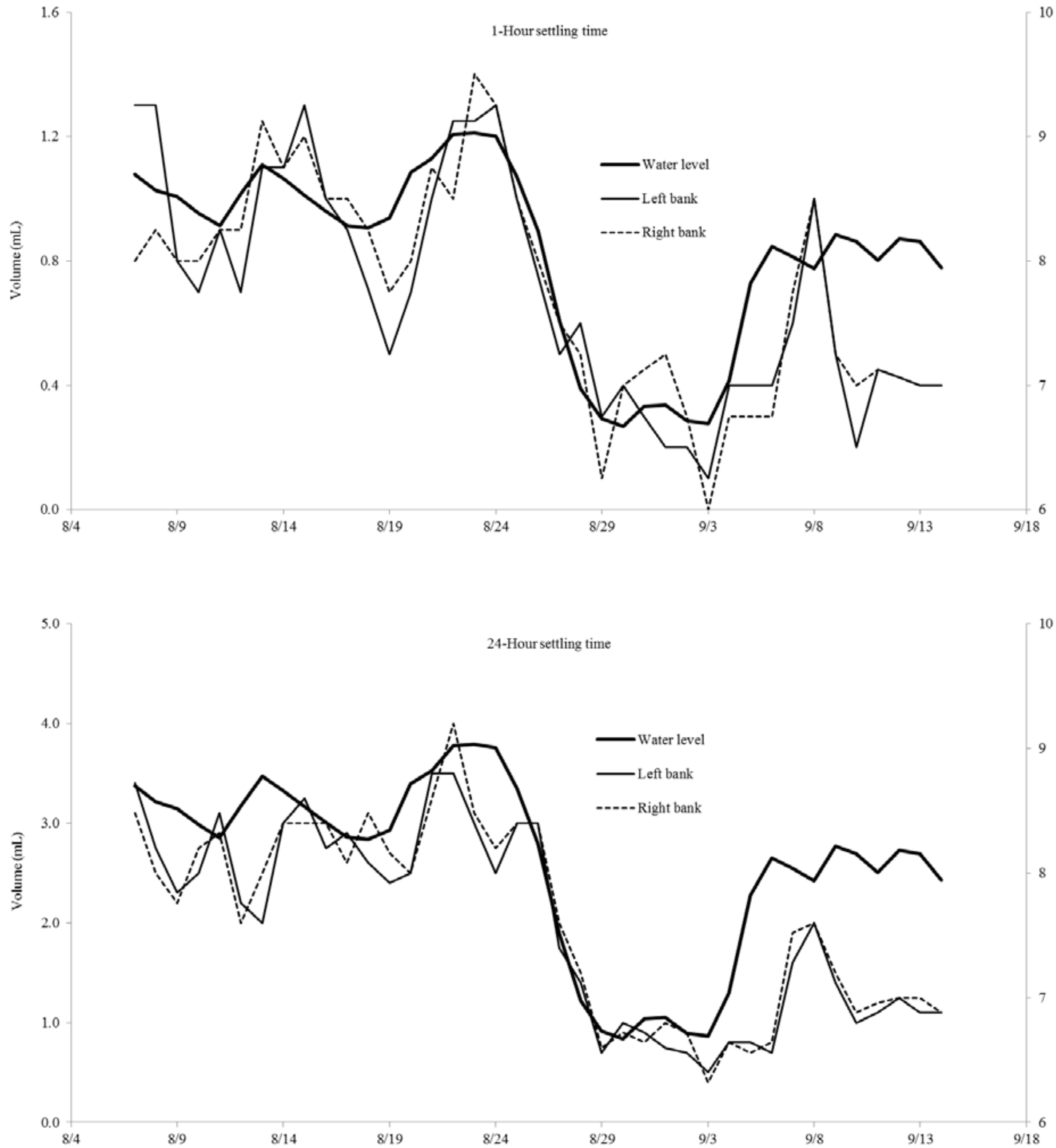


Figure 26.–Imhoff cone sediment volumes at settling times of 1 and 24 hours at the Tanana River sonar project, 2013, and daily Tanana River water level at the Nenana gaging station, 2013.

Source: Water level data obtained from United States Geological Service, Nenana gaging station, located 163 km upriver from the sonar site.

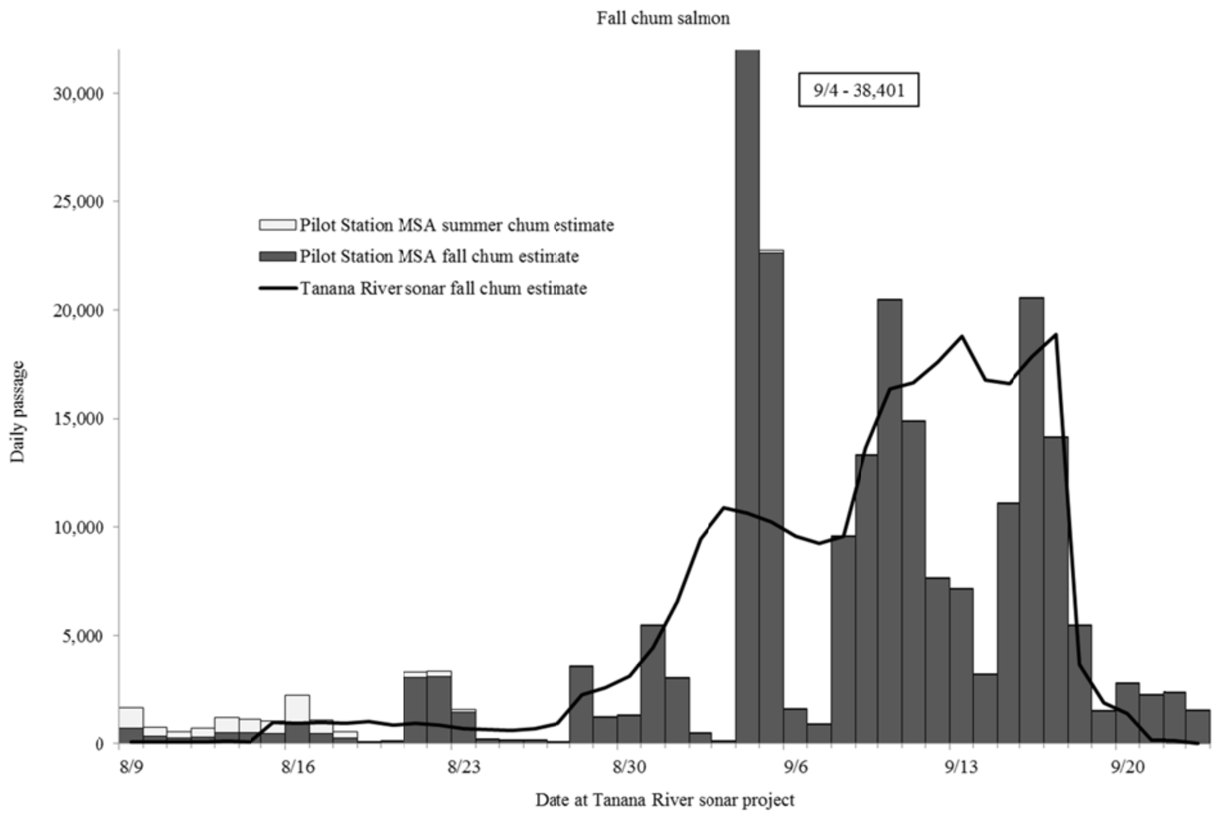


Figure 27.–Tanana River sonar project daily fall chum salmon estimates, and Pilot Station sonar project chum salmon mixed stock analysis (MSA) estimates, lagged 21 days from Pilot Station sonar, 2013.

Note: Pilot Station sonar mixed stock analysis estimates were calculated using stratified proportions. At the Tanana River sonar project, the left bank sonar did not operate August 20–27, and the right bank sonar did not operate August 7–14 and September 18–23. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23; and set gillnets fished September 10–23. Estimates are considered incomplete. The actual Pilot Station sonar total chum estimate on September 4 was 38,401.

Source: Pilot Station MSA proportions provided by B. G. Flannery, Geneticist, USFWS, Anchorage, personal communication.

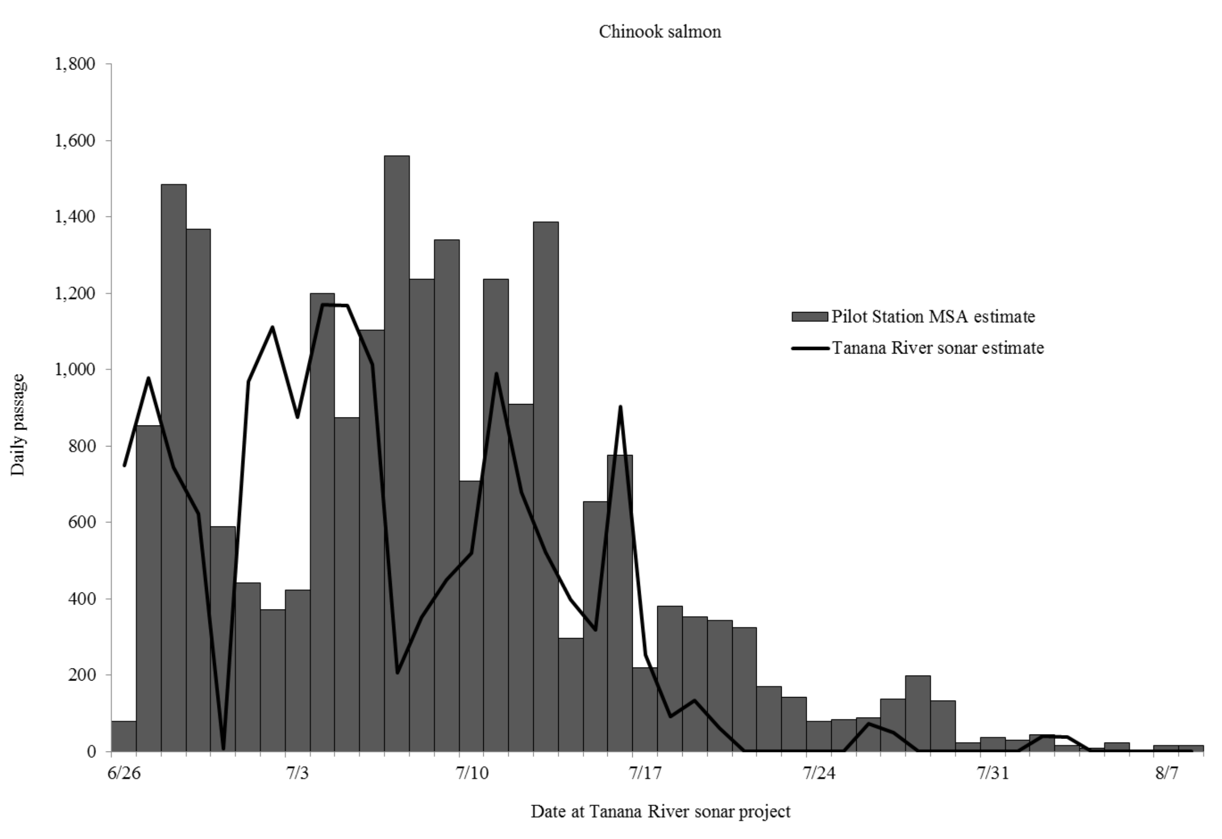


Figure 28.–Tanana River sonar project daily Chinook salmon estimates, and Pilot Station sonar project Chinook salmon mixed stock analysis (MSA) estimates, lagged 19 days from Pilot Station sonar, 2014.

Note: Pilot Station sonar mixed stock analysis estimates were calculated using stratified proportions. At the Tanana River sonar project, the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete.

Source: Pilot Station MSA proportions provided by N. A. DeCovich, Geneticist, ADF&G, Anchorage, personal communication.

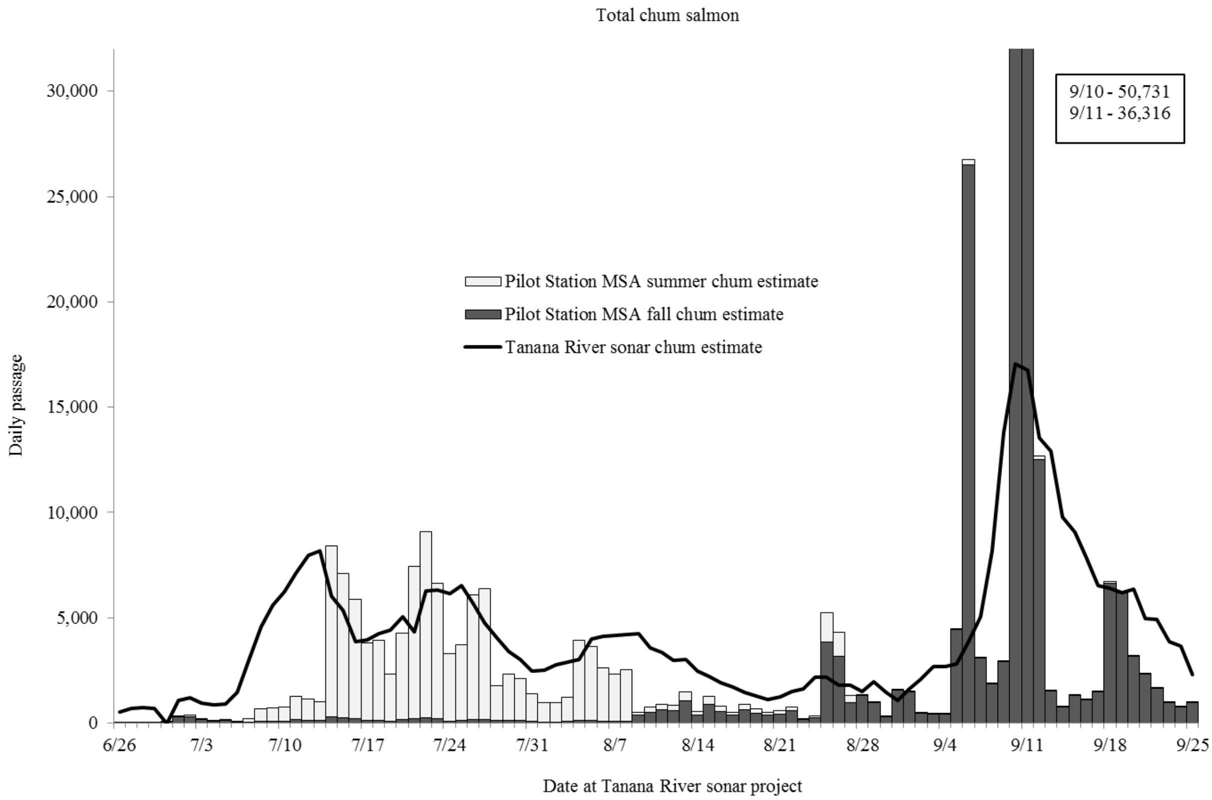


Figure 29.–Tanana River sonar project daily chum salmon estimates, and Pilot Station sonar project chum salmon mixed stock analysis (MSA) estimates, lagged 21 days from Pilot Station sonar, 2014.

Note: Pilot Station sonar mixed stock analysis estimates were calculated using stratified proportions. At the Tanana River sonar project, the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete. The actual Pilot Station sonar total chum salmon estimates on September 10 were 50,731 and on September 11 were 36,316.

Source: Pilot Station MSA proportions provided by B. G. Flannery, Geneticist, USFWS, Anchorage, personal communication.

APPENDIX A: DATA FORMS

Appendix A1.–Sonar data form used at the Tanana River sonar project.

SONAR COUNTS

Date:____________________

Bank:_______________

Initials	File Name	Stratum	Count	Thresholds Lower/Upper	QC Initials	QC Count

Notes:

Appendix A2.–Fish wheel data form used at the Tanana River sonar project.

Fall 2014 Tanana River Sonar Test Fish Data Form - Fish Wheel

Date:______/______ Period:________ Bank:__R__ Zone:__N__ Method:__W__

Video Reviewer:____________________ File Name:______________________________

S.O._____:_____:_____F.O._____:_____:_____S.I._____:_____:_____F.I._____:_____:_____

Chinook				Chum			Coho			Other/Tagged		
M	F	Small	UK	M	F	UK	M	F	UK	Species	Sex	Tag?

Video Notes:

Total Fish:

Date:______/______ Period:_______ Bank:___R___ Zone:___N___ Method:__W___

Crew:_____________________ Bottom of Axle Centered at Hole #:__________ Dip #:_________

S.O._____:_____:_____F.O._____:_____:_____S.I._____:_____:_____F.I._____:_____:_____

Fall Chum							Coho					
Sex	Length (mm)	Sex	Length (mm)	Sex	Length (mm)		Sex	Length (mm)	Sex	Length (mm)	Sex	Length (mm)

Other Species	Length	Other Species	Length		Other Species	Length	Other Species	Length

Fall Chum - Female	Fall Chum - Male		Coho - Female	Coho - Male
Total:	Total:		Total:	Total:

Retained Fish:

Wheel Notes:

Total Fish:

Rotations: **1st:**__________________ **Average:**________________

2nd:__________________

3rd:__________________

Stoppage:	**Stop time:**	**Start time:**	**Total:**
	Stop time:	**Start time:**	**Total:**
	Stop time:	**Start time:**	**Total:**

QC Initials:____________

Appendix A3.–Gillnet data form used at the Tanana River sonar project.

Summer 2014 Tanana River Sonar Test Fish Data Form

Date:_______/_______ Period:_______ Bank:________ Zone:________ Mesh (in):___________

Net Length (ftm):____________ Captain:_____________ Method:_____________

Net Depth (ft):_____________ LB Temp (C):______________ RB Temp (C):______________

S.O.______:______:______F.O.______:______:______S.I.______:______:______F.I.______:______:______

Chinook					**Summer Chum**					
Sex	Length (mm)	Card #	Scale #	Notes:	Sex	Length (mm)	Sex	Length (mm)	Sex	Length (mm)

Other Species	Length	**Other Species**	Length	**Fishing Notes:**

Retained Fish:

QC Initials:____________

Period:_______ Bank:________ Zone:________ Mesh (in):___________

Net Length (ftm):____________ Captain:_____________ Method:_____________

Net Depth (ft):_____________

S.O.______:______:______F.O.______:______:______S.I.______:______:______F.I.______:______:______

Chinook					**Summer Chum**					
Sex	Length (mm)	Card #	Scale #	Notes:	Sex	Length (mm)	Sex	Length (mm)	Sex	Length (mm)

Other Species	Length	**Other Species**	Length	**Fishing Notes:**

Retained Fish:

QC Initials:____________

APPENDIX B: TEST FISHERY ZONES USED IN SPECIES APPORTIONMENT

Appendix B1.–Test fishery zones assigned to each sonar stratum for each day at the Tanana River sonar project, 2013.

	Left bank			Right bank	
Date	S1	S2	S3	S1	S2
7/16	2	3	3	4	4
7/17	2	3	3	4	4
7/18	2	3	3	4	4
7/19	2	3	3	4	4
7/20	2	3	3	4	4
7/21	2	3	3	4	4
7/22	2	3	3	4	4
7/23	2	3	3	4	4
7/24	2	3	3	4	4
7/25	2	3	3	4	4
7/26	2	3	3	4	4
7/27	2	3	3	4	4
7/28	2	3	3	4	4
7/29	2	3	3	4	4
7/30	2	3	3	4	4
7/31	2	3	3	4	4
8/01	2	3	3	4	4
8/02	2	3	3	4	4
8/03	2	3	3	4	4
8/04	2	3	3	4	4
8/05	2	3	3	4	4
8/06	2	3	3	4	4
8/07	2	3	3	4	4
8/08	2	3	3	4	4
8/09	2	3	3	4	4
8/10	2	3	3	4	4
8/11	2	3	3	4	4
8/12	2	3	3	4	4
8/13	2	3	3	4	4
8/14	2	3	3	4	4
8/15	2	3	3	4	4
8/16	2	3	3	4	4
8/17	2	3	3	4	4
8/18	2	3	3	4	4
8/19	2	3	3	4	4
8/20	2	3	3	4	4
8/21	2	3	3	4	4
8/22	2	3	3	4	4
8/23	2	3	3	4	4
8/24	2	3	3	4	4
8/25	2	3	3	4	4
8/26	2	3	3	4	4

-continued-

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	Left bank			Right bank	
Date	S1	S2	S3	S1	S2
8/27	2	3	3	4	4
8/28	2	3	3	4	4
8/29	2	3	3	4	4
8/30	2	3	3	4	4
8/31	2	3	3	4	4
9/01	2	3	3	4	4
9/02	2	3	3	4	4
9/03	2	3	3	4	4
9/04	2	3	3	4	4
9/05	2	3	3	4	4
9/06	2	3	3	4	4
9/07	2	3	3	4	4
9/08	2	3	3	4	4
9/09	2	3	3	4	4
9/10	2	3	3	4	4
9/11	2	3	3	4	4
9/12	2	3	3	4	4
9/13	2	3	3	4	4
9/14	2	3	3	4	4
9/15	2	3	3	4	4
9/16	2	3	3	4	4
9/17	2	3	3	4	4
9/18	2	3	3	4	4
9/19	2	3	3	4	4
9/20	2	3	3	4	4
9/21	2	3	3	4	4
9/22	2	3	3	4	4
9/23	2	3	3	4	4

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). The left bank sonar operated July 13–September 23, but not on July 19 or August 20–27. The right bank sonar operated July 14–September 17, but not July 21–30 or August 7–14. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11, and consistently September 12–23; and set gillnets fished September 10–23.

Appendix B2.–Test fishery zones assigned to each sonar stratum for each day at the Tanana River sonar project, 2014.

	Left bank			Right bank	
Date	S1	S2	S3	S1	S2
6/26	2	3	3	1	1
6/27	2	3	3	1	1
6/28	2	3	3	1	1
6/29	2	3	3	1	1
6/30	2	3	3	1	1
7/01	2	3	3	1	1
7/02	2	3	3	1	1
7/03	2	3	3	1	1
7/04	3	3	3	1	1
7/05	3	3	3	1	1
7/06	3	3	3	1	1
7/07	3	3	3	1	1
7/08	3	3	3	1	1
7/09	3	3	3	1	1
7/10	3	3	3	1	1
7/11	3	3	3	4	4
7/12	3	3	3	4	4
7/13	3	3	3	4	4
7/14	2	3	3	4	4
7/15	2	3	3	4	4
7/16	2	3	3	4	4
7/17	2	3	3	4	4
7/18	2	3	3	4	4
7/19	2	3	3	4	4
7/20	2	3	3	4	4
7/21	2	3	3	4	4
7/22	3	3	3	4	4
7/23	3	3	3	4	4
7/24	3	3	3	4	4
7/25	3	3	3	4	4
7/26	3	3	3	4	4
7/27	2	3	3	4	4
7/28	2	3	3	4	4
7/29	2	3	3	4	4
7/30	2	3	3	4	4
7/31	2	3	3	4	4
8/01	2	3	3	4	4
8/02	2	3	3	4	4
8/03	2	3	3	4	4
8/04	2	3	3	1	1
8/05	2	3	3	4	4
8/06	2	3	3	4	4

-continued-

Appendix B2.–Page 2 of 3.

	Left bank			Right bank	
Date	S1	S2	S3	S1	S2
8/07	2	3	3	4	4
8/08	2	3	3	4	4
8/09	2	3	3	4	4
8/10	2	3	3	4	4
8/11	2	3	3	4	4
8/12	2	3	3	4	4
8/13	2	3	3	4	4
8/14	2	3	3	4	4
8/15	2	3	3	4	4
8/16	2	3	3	4	4
8/17	2	3	3	4	4
8/18	2	3	3	4	4
8/19	2	3	3	4	4
8/20	2	3	3	4	4
8/21	2	3	3	4	4
8/22	2	3	3	4	4
8/23	2	3	3	4	4
8/24	2	3	3	4	4
8/25	2	3	3	4	4
8/26	2	3	3	4	4
8/27	2	3	3	4	4
8/28	2	3	3	4	4
8/29	2	3	3	4	4
8/30	2	3	3	4	4
8/31	2	3	3	4	4
9/01	2	3	3	4	4
9/02	2	3	3	4	4
9/03	2	3	3	4	4
9/04	2	3	3	4	4
9/05	2	3	3	4	4
9/06	2	3	3	4	4
9/07	2	3	3	4	4
9/08	2	3	3	4	4
9/09	2	3	3	4	4
9/10	2	3	3	4	4
9/11	2	3	3	4	4
9/12	2	3	3	4	4
9/13	2	3	3	4	4
9/14	2	3	3	4	4
9/15	2	3	3	4	4
9/16	2	3	3	4	4
9/17	2	3	3	4	4
9/18	2	3	3	4	4

-continued-

Appendix B2.–Page 3 of 3.

	Left bank			Right bank	
Date	S1	S2	S3	S1	S2
9/19	2	3	3	4	4
9/20	2	3	3	4	4
9/21	2	3	3	4	4
9/22	2	3	3	4	4
9/23	2	3	3	4	4
9/24	2	3	3	1	1
9/25	2	3	3	1	1

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). The left and right bank sonars operated June 26–September 25, but the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not on August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27.

APPENDIX C: REPORTING UNITS USED IN SPECIES APPORTIONMENT

Appendix C1.–Reporting units compiled for the 2013 season at the Tanana River sonar project.

	Right bank		Left bank	
	Nearshore	Nearshore	Nearshore	Offshore
Date	Zone 1 - DG	Zone 4 - FW	Zone 2 - DG/SG	Zone 3 - DG
7/16	100	400	200	300
7/17				
7/18		401		
7/19		402		
7/20		403		
7/21				
7/22		404		
7/23		405		
7/24		406		
7/25		407		
7/26		408		
7/27		409		
7/28				
7/29		410		
7/30		411		
7/31		412		
8/01		413		
8/02		414		
8/03		415		
8/04		416		
8/05		417		
8/06		418		
8/07		419		
8/08		420		
8/09		421		
8/10		422		
8/11		423		
8/12		424		
8/13		425		
8/14		426		
8/15		427		
8/16		428		
8/17		429		
8/18		430		
8/19		431		
8/20		432		
8/21		433		
8/22		434		
8/23		435		
8/24		436		
8/25		437		
8/26		438		
8/27		439		

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	Right bank		Left bank	
	Nearshore	Nearshore	Nearshore	Offshore
Date	Zone 1 - DG	Zone 4 - FW	Zone 2 - DG/SG	Zone 3 - DG
8/28		440		
8/29		441		
8/30		442		
8/31		443		
9/01		444		
9/02		445		
9/03		446		
9/04		447		
9/05	101	448		301
9/06		449		
9/07		450		
9/08		451		
9/09		452		
9/10		453		
9/11		454		
9/12		455	201	
9/13	102	456		
9/14		457	202	302
9/15	103	458	203	
9/16		459	204	303
9/17	104	460		
9/18		461		304
9/19	105	462	205	
9/20				
9/21		463		305
9/22	106	464	206	
9/23		465	207	

Note: DG = drift gillnets; SG = set gillnets; FW = fish wheel. The left bank sonar operated July 13–September 23, but not on July 19 or August 20–27. The right bank sonar operated July 14–September 17, but not July 21–30 or August 7–August 14. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23; and set gillnets fished September 10–23.

Appendix C2.–Reporting units compiled for the 2014 season at the Tanana River sonar project.

	Right bank		Left bank	
	Nearshore	Nearshore	Nearshore	Offshore
Date	Zone 1 - DG	Zone 4 - FW	Zone 2 - DG/SG	Zone 3 - DG
6/26	100	0	200	300
6/27				
6/28				301
6/29				
6/30				
7/01				
7/02				
7/03				
7/04				
7/05				
7/06				302
7/07	101			
7/08				
7/09				
7/10				
7/11	102	400		
7/12		401	201	
7/13	103	402		
7/14		403		303
7/15	104	404	202	
7/16		405		304
7/17	105	406		
7/18		407		305
7/19	106	408	203	
7/20		409		306
7/21	107	410		
7/22				307
7/23	108	411		
7/24				308
7/25	109	412		
7/26		413	204	309
7/27	110	414		
7/28		415		
7/29	111	416		
7/30		417		
7/31	112	418		
8/01		419		
8/02	113	420		
8/03				
8/04	114	421		
8/05			205	
8/06	115	422		

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	Right bank		Left bank	
	Nearshore	Nearshore	Nearshore	Offshore
Date	Zone 1 - DG	Zone 4 - FW	Zone 2 - DG/SG	Zone 3 - DG
8/07				
8/08		423		
8/09	116	424	206	310
8/10		425		
8/11		426		
8/12	117	427		
8/13		428	207	
8/14	118	429		
8/15		430		
8/16	119	431		
8/17		432		
8/18	120	433	208	
8/19		434		
8/20	121			
8/21		435		
8/22				
8/23	122	436		311
8/24		437		
8/25	123	438		
8/26		439	209	
8/27	124	440		
8/28		441	210	312
8/29	125	442	211	
8/30		443	212	313
8/31	126	444	213	
9/01	127	445	214	
9/02	128	446	215	314
9/03	129	447	216	
9/04	130	448	217	
9/05	131	449	218	
9/06			219	315
9/07	132	450	220	
9/08	133	451	221	
9/09	134	452	222	316
9/10	135	453	223	
9/11	136	454	224	317
9/12	137	455	225	
9/13	138	456	226	318
9/14	139	457	227	
9/15	140	458	228	319
9/16	141	459	229	
9/17	142	460	230	320

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	Right bank		Left bank	
	Nearshore	Nearshore	Nearshore	Offshore
Date	Zone 1 - DG	Zone 4 - FW	Zone 2 - DG/SG	Zone 3 - DG
9/18	143	461	231	
9/19	143	462	232	321
9/20	144	463	233	
9/21	145	464	234	322
9/22	146	465	235	
9/23	147	466	236	323
9/24	148		237	
9/25	149		238	

Note: DG = gillnets; SG = set gillnets; FW = fish wheel. The left and right bank sonars were operated June 26–September 25, but the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27.

APPENDIX D: NET SELECTIVITY PARAMETERS USED IN SPECIES APPORTIONMENT

Appendix D1.–Net selectivity parameters used for species apportionment at the Tanana River sonar project, 2013 and 2014.

Species	Tau	Sigma	Theta	Lambda	Tangle
Large Chinook[a]	1.9008	0.2050	0.5923	-0.4334	0.0239
Small Chinook[b]	1.9008	0.2050	0.5923	-0.4334	0.0239
Summer chum	1.9699	0.1543	0.7504	-0.4841	0.0000
Fall chum	1.8632	0.2330	1.1954	-1.4361	0.0303
Coho	1.9827	0.3269	0.8686	-1.4557	0.1185
Pink	1.9805	0.2598	1.5542	1.2820	0.1649
Broad whitefish	1.7774	0.2205	1.4018	-1.9341	0.0981
Humpback whitefish	1.9021	0.2320	1.1103	-2.0546	0.0642
Cisco	2.0830	0.2223	1.8771	-1.6381	0.1809
Other	2.2604	0.3642	0.9881	-2.2990	0.0000

[a] Chinook salmon >655 mm.

[b] Chinook salmon ≤655 mm.

APPENDIX E: DAILY FISH PASSAGE ESTIMATES BY STRATUM

Appendix E1.–Daily fish passage estimates by stratum, with standard errors (SE), at the Tanana River sonar project, 2013.

	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
7/13	832	233.4	106	32.9	ND	ND	ND	ND	ND	ND	938	ND	938
7/14	439	34.3	94	9.7	ND	ND	1,936	102.7	ND	ND	533	1,936	2,469
7/15	478	35.5	157	17.6	ND	ND	1,309	ND	ND	ND	635	1,309	1,944
7/16	688	36.6	176	13.9	ND	ND	1,982	54.8	ND	ND	864	1,982	2,846
7/17	1,483	60.7	165	18.4	ND	ND	2,126	39.5	ND	ND	1,648	2,126	3,774
7/18	2,041	68.0	134	11.4	ND	ND	2,070	25.8	ND	ND	2,175	2,070	4,245
7/19	ND	ND	ND	ND	ND	ND	2,527	68.2	ND	ND	ND	2,527	2,527
7/20	2,699	191.5	120	16.0	ND	ND	2,433	115.4	ND	ND	2,819	2,433	5,252
7/21	3,460	129.4	44	6.2	ND	ND	ND	ND	ND	ND	3,504	ND	3,504
7/22	4,489	98.4	45	8.6	ND	ND	ND	ND	ND	ND	4,534	ND	4,534
7/23	5,702	94.8	84	9.7	ND	ND	ND	ND	ND	ND	5,786	ND	5,786
7/24	4,785	110.8	61	12.7	ND	ND	ND	ND	ND	ND	4,846	ND	4,846
7/25	3,865	151.1	31	6.1	ND	ND	ND	ND	ND	ND	3,896	ND	3,896
7/26	3,978	91.1	10	3.1	ND	ND	ND	ND	ND	ND	3,988	ND	3,988
7/27	3,949	186.0	10	4.1	ND	ND	ND	ND	ND	ND	3,959	ND	3,959
7/28	2,548	118.0	26	7.8	ND	ND	ND	ND	ND	ND	2,574	ND	2,574
7/29	2,041	64.7	9	4.3	ND	ND	ND	ND	ND	ND	2,050	ND	2,050
7/30	1,608	32.5	15	3.8	ND	ND	ND	ND	ND	ND	1,623	ND	1,623
7/31	2,003	74.7	3	2.4	ND	ND	1,782	101.3	ND	ND	2,006	1,782	3,788
8/01	2,068	91.3	7	2.2	ND	ND	1,310	5.8	ND	ND	2,075	1,310	3,385
8/02	1,440	71.5	12	3.1	ND	ND	1,321	0.0	ND	ND	1,452	1,321	2,773
8/03	1,234	69.9	2	1.4	ND	ND	1,199	4.4	ND	ND	1,236	1,199	2,435
8/04	1,062	39.7	50	5.9	ND	ND	1,054	0.0	ND	ND	1,112	1,054	2,166
8/05	1,162	41.2	17	3.9	ND	ND	983	2.5	ND	ND	1,179	983	2,162
8/06	1,246	59.7	23	4.5	ND	ND	956	33.1	ND	ND	1,269	956	2,225
8/07	877	39.8	2	1.5	ND	ND	ND	ND	ND	ND	879	ND	879
8/08	836	33.2	4	1.9	ND	ND	ND	ND	ND	ND	840	ND	840
8/09	793	32.1	10	2.5	ND	ND	ND	ND	ND	ND	803	ND	803

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	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
8/10	705	28.7	19	4.5	ND	ND	ND	ND	ND	ND	724	ND	724
8/11	636	28.2	19	4.5	ND	ND	ND	ND	ND	ND	655	ND	655
8/12	647	32.0	14	4.6	ND	ND	ND	ND	ND	ND	661	ND	661
8/13	778	27.2	63	8.3	ND	ND	ND	ND	ND	ND	841	ND	841
8/14	785	40.2	18	5.2	ND	ND	ND	ND	ND	ND	803	ND	803
8/15	842	33.9	44	5.7	ND	ND	863	78.8	ND	ND	886	863	1,749
8/16	830	36.7	70	8.2	ND	ND	819	0.0	ND	ND	900	819	1,719
8/17	755	27.3	76	8.4	ND	ND	856	0.0	ND	ND	831	856	1,687
8/18	523	42.2	73	10.2	ND	ND	897	2.7	ND	ND	596	897	1,493
8/19	494	42.1	171	16.8	ND	ND	829	0.0	ND	ND	665	829	1,494
8/20	ND	ND	ND	ND	ND	ND	922	0.0	ND	ND	ND	922	922
8/21	ND	ND	ND	ND	ND	ND	986	94.9	ND	ND	ND	986	986
8/22	ND	ND	ND	ND	ND	ND	885	0.0	ND	ND	ND	885	885
8/23	ND	ND	ND	ND	ND	ND	729	0.0	ND	ND	ND	729	729
8/24	ND	ND	ND	ND	ND	ND	812	15.8	ND	ND	ND	812	812
8/25	ND	ND	ND	ND	ND	ND	641	0.0	ND	ND	ND	641	641
8/26	ND	ND	ND	ND	ND	ND	803	0.0	ND	ND	ND	803	803
8/27	ND	ND	ND	ND	ND	ND	1,141	10.6	ND	ND	ND	1,141	1,141
8/28	344	27.2	1,048	61.3	ND	ND	1,572	0.0	ND	ND	1,392	1,572	2,964
8/29	422	27.7	1,094	51.7	ND	ND	1,970	0.0	ND	ND	1,516	1,970	3,486
8/30	497	21.2	1,368	34.6	ND	ND	2,489	23.9	ND	ND	1,865	2,489	4,354
8/31	717	33.5	1,990	75.6	ND	ND	2,988	36.1	ND	ND	2,707	2,988	5,695
9/01	982	36.9	3,092	121.2	ND	ND	4,020	0.0	ND	ND	4,074	4,020	8,094
9/02	1,160	56.4	4,036	99.7	ND	ND	6,226	0.0	ND	ND	5,196	6,226	11,422
9/03	902	52.7	3,967	171.4	ND	ND	7,832	0.0	ND	ND	4,869	7,832	12,701
9/04	774	45.7	3,118	141.6	ND	ND	8,429	0.0	ND	ND	3,892	8,429	12,321
9/05	1,066	46.1	4,394	132.2	ND	ND	7,481	0.0	ND	ND	5,460	7,481	12,941
9/06	2,425	143.6	4,625	114.6	ND	ND	7,451	0.0	ND	ND	7,050	7,451	14,501

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	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
9/07	5,698	374.0	4,388	295.4	20	10.5	7,038	16.2	ND	ND	10,106	7,038	17,144
9/08	11,620	379.5	1,891	71.2	10	5.3	8,291	124.4	13	9.8	13,521	8,304	21,825
9/09	8,766	451.7	2,901	180.6	3	2.5	12,163	348.8	24	5.0	11,670	12,187	23,857
9/10	8,997	408.0	4,353	106.0	27	9.5	12,910	276.5	46	10.6	13,377	12,956	26,333
9/11	7,527	266.2	5,493	297.0	15	6.7	13,768	467.9	88	11.7	13,035	13,856	26,891
9/12	4,575	202.0	6,363	316.0	24	6.2	13,548	262.1	32	7.3	10,962	13,580	24,542
9/13	4,257	156.0	7,332	305.0	12	5.1	13,892	290.8	42	7.5	11,601	13,934	25,535
9/14	2,448	217.5	7,143	413.8	36	11.0	14,970	386.7	54	9.1	9,627	15,024	24,651
9/15	1,296	82.5	5,685	310.9	27	4.0	16,064	296.6	58	7.9	7,008	16,122	23,130
9/16	957	118.6	4,361	195.0	48	12.7	16,664	354.5	116	13.6	5,366	16,780	22,146
9/17	1,290	118.8	6,045	309.8	48	12.1	16,852	550.1	39	11.7	7,383	16,891	24,274
9/18	1,557	87.2	5,661	360.9	39	6.2	ND	ND	ND	ND	7,257	ND	7,257
9/19	1,284	69.0	3,462	256.6	12	11.7	ND	ND	ND	ND	4,758	ND	4,758
9/20	1,827	88.1	2,448	180.7	30	9.3	ND	ND	ND	ND	4,305	ND	4,305
9/21	1,602	97.9	1,620	78.1	11	5.7	ND	ND	ND	ND	3,233	ND	3,233
9/22	1,812	95.9	1,479	138.1	9	4.0	ND	ND	ND	ND	3,300	ND	3,300
9/23	1,779	108.1	1,137	49.3	3	2.5	ND	ND	ND	ND	2,919	ND	2,919
Total	141,382	6,440.6	102,478	5,160.1	374	125.0	230,789	4,190.7	512	94.2	244,234	231,301	475,535

Note: The left bank sonar operated July 13–September 23, but not July 19 or August 20–27. The right bank sonar operated July 14–September 17, but not July 21–30 or August 7–14.

Appendix E2.–Daily fish passage estimates by stratum, with standard errors (SE), at the Tanana River sonar project, 2014.

	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
6/26	354	39.9	256	38.5	ND	ND	939	61.2	104	25.2	610	1,043	1,653
6/27	492	32.1	346	24.0	ND	ND	1,279	48.0	57	15.4	838	1,336	2,174
6/28	530	76.5	96	32.8	ND	ND	1,390	110.5	12	12.6	626	1,402	2,028
6/29	ND	ND	ND	ND	ND	ND	1,315	80.0	ND	ND	ND	1,315	1,315
6/30	117	14.4	9	3.2	ND	ND	ND	ND	ND	ND	126	ND	126
7/01	229	24.8	2	1.8	ND	ND	2,007	166.4	36	14.3	231	2,043	2,274
7/02	363	21.5	51	13.1	0	0.0	2,202	61.8	56	10.2	414	2,258	2,672
7/03	512	47.8	10	4.1	0	0.0	1,785	40.9	46	9.5	522	1,831	2,353
7/04	523	53.6	12	5.1	0	0.0	1,493	80.2	23	12.8	535	1,516	2,051
7/05	512	42.7	0	0.0	0	0.0	1,532	75.7	24	10.2	512	1,556	2,068
7/06	447	28.2	3	2.5	0	0.0	2,020	45.6	21	9.0	450	2,041	2,491
7/07	511	59.0	67	16.2	0	0.0	2,595	60.1	13	3.8	578	2,608	3,186
7/08	1,157	66.8	310	33.6	0	0.0	3,369	93.2	111	19.7	1,467	3,480	4,947
7/09	1,620	77.7	558	70.1	0	0.0	3,825	114.5	45	12.4	2,178	3,870	6,048
7/10	2,002	122.6	774	74.1	0	0.0	3,965	106.2	33	12.5	2,776	3,998	6,774
7/11	2,204	114.5	1,082	119.7	0	0.0	4,800	131.1	47	19.0	3,286	4,847	8,133
7/12	2,390	93.2	1,023	81.0	6	3.6	5,290	139.2	39	7.4	3,419	5,329	8,748
7/13	2,163	120.2	1,037	88.5	0	0.0	5,467	186.1	48	18.8	3,200	5,515	8,715
7/14	2,138	144.4	1,335	82.1	6	3.6	4,768	159.1	26	11.0	3,479	4,794	8,273
7/15	1,909	99.4	1,404	95.1	3	2.5	4,156	94.9	21	11.0	3,316	4,177	7,493
7/16	1,611	73.6	845	44.5	0	0.0	3,699	100.5	42	10.6	2,456	3,741	6,197
7/17	1,130	67.5	885	72.8	0	0.0	3,150	105.3	27	4.7	2,015	3,177	5,192
7/18	1,063	53.9	957	46.6	0	0.0	3,230	66.6	36	9.9	2,020	3,266	5,286
7/19	1,074	79.1	837	64.7	0	0.0	3,305	79.3	38	8.4	1,911	3,343	5,254
7/20	1,213	45.7	905	148.0	0	0.0	3,608	62.1	99	16.1	2,118	3,707	5,825
7/21	2,203	100.9	213	21.2	0	0.0	3,120	252.1	90	17.4	2,416	3,210	5,626
7/22	2,197	99.3	174	15.2	3	2.9	3,821	194.4	76	31.0	2,374	3,897	6,271
7/23	1,656	84.8	34	5.6	0	0.0	4,542	129.5	102	18.0	1,690	4,644	6,334

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	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
7/24	1,002	46.8	0	0.0	0	0.0	5,049	68.3	105	15.8	1,002	5,154	6,156
7/25	1,490	65.7	5	3.2	0	0.0	4,937	124.8	93	15.2	1,495	5,030	6,525
7/26	1,092	ND	0	ND	0	ND	4,580	100.6	72	16.9	1,092	4,652	5,744
7/27	1,175	82.6	4	3.3	0	0.0	3,767	104.5	27	9.1	1,179	3,794	4,973
7/28	729	56.6	3	2.5	0	0.0	3,244	71.2	50	9.7	732	3,294	4,026
7/29	780	45.1	3	3.0	0	0.0	2,542	61.1	100	16.1	783	2,642	3,425
7/30	869	40.9	9	2.5	0	0.0	2,113	49.7	87	22.1	878	2,200	3,078
7/31	628	36.9	7	4.2	0	0.0	1,841	55.0	54	12.8	635	1,895	2,530
8/01	537	25.6	9	3.1	6	3.6	1,914	43.2	54	9.0	552	1,968	2,520
8/02	778	40.4	12	4.0	0	0.0	1,970	52.8	48	10.5	790	2,018	2,808
8/03	993	40.7	17	4.2	0	0.0	1,898	81.3	39	10.9	1,010	1,937	2,947
8/04	894	81.2	3	2.5	0	0.0	2,652	61.0	42	9.7	897	2,694	3,591
8/05	831	36.3	3	2.7	0	0.0	3,211	69.9	26	9.3	834	3,237	4,071
8/06	819	46.3	0	0.0	0	0.0	3,456	85.8	27	9.0	819	3,483	4,302
8/07	649	44.8	0	0.0	0	0.0	3,606	77.2	54	13.0	649	3,660	4,309
8/08	824	71.5	19	8.8	0	0.0	3,373	94.3	50	9.5	843	3,423	4,266
8/09	1,325	59.4	12	6.2	0	0.0	3,212	62.4	9	4.3	1,337	3,221	4,558
8/10	655	35.3	32	14.7	0	0.0	3,000	64.4	42	10.6	687	3,042	3,729
8/11	553	34.0	15	6.7	0	0.0	2,894	56.4	33	6.6	568	2,927	3,495
8/12	459	20.9	57	10.7	3	2.7	2,558	64.1	48	12.6	519	2,606	3,125
8/13	630	23.5	57	10.1	0	0.0	2,326	56.4	63	8.8	687	2,389	3,076
8/14	492	39.7	43	15.3	0	0.0	1,992	54.7	52	12.3	535	2,044	2,579
8/15	557	47.8	22	7.0	3	2.5	1,682	62.3	18	5.3	582	1,700	2,282
8/16	434	35.2	18	6.2	0	0.0	1,480	53.6	21	6.1	452	1,501	1,953
8/17	351	33.0	15	5.1	3	2.5	1,362	39.1	18	7.9	369	1,380	1,749
8/18	378	39.3	21	8.5	7	3.0	1,056	40.3	12	6.1	406	1,068	1,474
8/19	369	30.7	6	3.6	3	2.5	1,082	49.2	21	7.5	378	1,103	1,481
8/20	270	25.7	6	3.6	0	0.0	1,012	30.7	24	9.0	276	1,036	1,312

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	Left bank						Right bank				Total		
	S1		S2		S3		S1		S2				
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
8/21	394	37.2	14	4.7	3	2.7	976	37.5	18	5.6	411	994	1,405
8/22	460	30.4	33	8.4	0	0.0	1,176	26.0	15	5.0	493	1,191	1,684
8/23	673	48.8	57	14.8	0	0.0	1,234	40.1	30	10.2	730	1,264	1,994
8/24	777	69.3	106	18.3	3	2.7	1,518	62.2	36	7.0	886	1,554	2,440
8/25	916	35.4	135	9.6	3	2.5	1,521	49.7	15	5.3	1,054	1,536	2,590
8/26	729	56.7	106	24.7	3	3.0	1,916	47.1	27	8.5	838	1,943	2,781
8/27	1,056	62.6	12	6.4	0	0.0	1,828	54.4	35	10.0	1,068	1,863	2,931
8/28	1,128	72.2	6	2.7	0	0.0	1,900	49.6	29	9.8	1,134	1,929	3,063
8/29	1,351	130.6	4	2.6	0	0.0	1,438	39.5	27	7.5	1,355	1,465	2,820
8/30	1,044	47.1	27	6.2	3	2.5	1,568	33.2	15	6.6	1,074	1,583	2,657
8/31	999	46.7	45	7.4	0	0.0	1,598	48.3	42	10.2	1,044	1,640	2,684
9/01	894	37.7	27	7.2	0	0.0	1,575	47.3	22	8.7	921	1,597	2,518
9/02	1,163	89.4	48	11.4	7	3.3	1,839	37.0	29	7.4	1,218	1,868	3,086
9/03	1,761	32.9	51	10.3	18	7.2	1,818	59.1	63	8.3	1,830	1,881	3,711
9/04	1,865	58.1	26	13.9	0	0.0	1,682	63.6	7	3.9	1,891	1,689	3,580
9/05	1,179	62.6	6	3.6	0	0.0	2,801	79.5	48	15.9	1,185	2,849	4,034
9/06	1,318	68.8	4	2.8	0	0.0	3,957	96.6	34	8.9	1,322	3,991	5,313
9/07	2,105	181.0	10	4.8	0	0.0	4,686	159.4	120	22.9	2,115	4,806	6,921
9/08	2,742	109.4	183	21.8	18	7.6	6,826	178.0	265	32.9	2,943	7,091	10,034
9/09	4,773	440.5	150	15.9	6	3.6	10,798	262.1	363	38.5	4,929	11,161	16,090
9/10	8,043	428.4	154	23.0	38	12.3	12,666	326.8	477	70.1	8,235	13,143	21,378
9/11	7,278	558.2	132	17.9	96	15.2	14,246	437.3	279	35.4	7,506	14,525	22,031
9/12	6,682	439.8	177	26.8	57	14.6	11,524	276.2	273	44.5	6,916	11,797	18,713
9/13	6,279	375.5	21	6.4	27	5.9	11,753	440.8	374	56.8	6,327	12,127	18,454
9/14	4,743	295.4	21	6.7	66	15.1	9,618	227.7	294	41.5	4,830	9,912	14,742
9/15	5,016	290.7	29	5.5	22	9.1	9,266	259.1	336	34.7	5,067	9,602	14,669
9/16	4,707	292.6	18	5.9	45	8.2	7,314	276.5	540	120.1	4,770	7,854	12,624
9/17	4,950	315.4	12	4.0	44	15.3	5,512	138.4	417	43.6	5,006	5,929	10,935

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	Left bank						Right bank						
	S1		S2		S3		S1		S2		Total		
Date	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	L bank	R bank	Overall
9/18	4,021	431.5	10	2.7	6	3.9	5,688	146.6	351	50.9	4,037	6,039	10,076
9/19	3,348	192.7	0	0.0	0	0.0	6,140	137.5	183	20.3	3,348	6,323	9,671
9/20	2,613	163.3	93	22.3	0	0.0	6,564	174.0	165	26.0	2,706	6,729	9,435
9/21	2,637	123.4	9	4.4	0	0.0	5,292	148.7	202	49.2	2,646	5,494	8,140
9/22	2,559	154.8	15	6.2	0	0.0	5,354	164.5	153	17.3	2,574	5,507	8,081
9/23	2,229	126.0	3	1.8	0	0.0	4,384	120.5	126	15.4	2,232	4,510	6,742
9/24	1,773	102.9	12	8.0	0	0.0	3,760	114.6	81	13.5	1,785	3,841	5,626
9/25	1,224	92.7	6	3.6	0	0.0	3,762	101.7	45	8.3	1,230	3,807	5,037
Total	148,312	9,170.8	15,385	1,689.0	508	164.3	331,979	9,639.9	8,097	1,527.6	164,205	340,076	504,281

Note: The left and right bank sonars operated June 26–September 25, but the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30.

APPENDIX F: DAILY FISH PASSAGE ESTIMATES BY SPECIES

Appendix F1.–Daily fish passage estimates by species at the Tanana River sonar project, 2013.

Date	Chinook	S chum	F chum	Coho	Other	Total
7/16	681	1,301	214	15	635	2,846
7/17	731	1,395	265	14	1,369	3,774
7/18	448	1,622	280	11	1,884	4,245
7/19	200	2,128	0	0	200	2,528
7/20	238	2,098	318	10	2,588	5,252
7/21	0	0	307	4	3,194	3,505
7/22	0	0	387	4	4,144	4,535
7/23	0	0	516	7	5,263	5,786
7/24	0	0	424	5	4,417	4,846
7/25	0	0	326	3	3,568	3,897
7/26	0	0	315	1	3,672	3,988
7/27	0	0	313	1	3,645	3,959
7/28	0	0	220	2	2,352	2,574
7/29	0	0	165	1	1,884	2,050
7/30	0	0	138	1	1,484	1,623
7/31	0	1,735	157	0	1,896	3,788
8/01	0	1,285	166	1	1,934	3,386
8/02	39	1,282	122	1	1,329	2,773
8/03	0	1,170	97	0	1,168	2,435
8/04	0	1,054	128	4	980	2,166
8/05	0	945	105	1	1,110	2,161
8/06	0	956	117	2	1,150	2,225
8/07	0	0	69	0	810	879
8/08	0	0	68	0	772	840
8/09	0	0	70	1	732	803
8/10	0	0	72	2	651	725
8/11	0	0	66	2	587	655
8/12	0	0	63	1	597	661
8/13	0	0	118	5	718	841
8/14	0	0	77	1	725	803
8/15	0	0	968	4	777	1,749
8/16	0	0	947	6	766	1,719
8/17	0	0	984	6	697	1,687
8/18	0	0	951	6	536	1,493
8/19	0	0	1,024	14	456	1,494
8/20	0	0	873	49	0	922
8/21	0	0	947	0	39	986
8/22	0	0	845	40	0	885
8/23	0	0	691	38	0	729
8/24	0	0	669	143	0	812
8/25	0	0	615	0	26	641
8/26	0	0	683	120	0	803
8/27	0	0	954	150	37	1,141
8/28	0	0	2,280	296	387	2,963

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Date	Chinook	S chum	F chum	Coho	Other	Total
8/29	0	0	2,570	481	435	3,486
8/30	0	0	3,138	699	517	4,354
8/31	0	0	4,460	542	693	5,695
9/01	0	0	6,567	575	952	8,094
9/02	0	0	9,439	844	1,139	11,422
9/03	0	0	10,913	926	862	12,701
9/04	0	0	10,667	900	755	12,322
9/05	0	0	10,218	984	1,739	12,941
9/06	0	0	9,597	1,871	3,033	14,501
9/07	0	0	9,238	1,831	6,075	17,144
9/08	0	0	9,595	1,146	11,084	21,825
9/09	0	0	13,657	1,519	8,682	23,858
9/10	0	0	16,375	725	9,233	26,333
9/11	0	0	16,649	2,153	8,089	26,891
9/12	0	0	17,582	2,206	4,753	24,541
9/13	0	0	18,782	2,221	4,532	25,535
9/14	0	0	16,777	2,989	4,884	24,650
9/15	0	0	16,611	3,190	3,330	23,131
9/16	0	0	17,829	2,794	1,523	22,146
9/17	0	0	18,881	3,292	2,101	24,274
9/18	0	0	3,658	2,663	936	7,257
9/19	0	0	1,908	1,699	1,151	4,758
9/20	0	0	1,408	1,375	1,522	4,305
9/21	0	0	143	762	2,327	3,232
9/22	0	0	170	519	2,611	3,300
9/23	0	0	43	351	2,525	2,919
Total	2,337	16,971	265,989	40,229	144,662	470,188
SE	222	272	8,517	2,105	9,485	12,925
CV	0.095	0.016	0.032	0.052	0.066	0.027
Lower 90% CI	1,972	16,524	251,979	36,766	129,059	448,926
Upper 90% CI	2,702	17,418	279,999	43,692	160,265	491,450

Note: The left bank sonar operated July 13–September 23, but not July 19 or August 20–27. The right bank sonar operated July 14–September 17, but not July 21–30 or August 7–14. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23; and set gillnets fished September 10–23. The Chinook and summer chum salmon estimates are from the right bank only, and estimates for all species are considered incomplete. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

Appendix F2.–Daily fish passage estimates by species at the Tanana River sonar project, 2014.

Date	Chinook	S chum	F chum	Coho	Other	Total
6/26	750	549	0	0	354	1,653
6/27	978	704	0	0	492	2,174
6/28	745	753	0	0	530	2,028
6/29	623	692	0	0	0	1,315
6/30	8	1	0	0	117	126
7/01	969	1,076	0	0	229	2,274
7/02	1,112	1,197	0	0	363	2,672
7/03	875	966	0	0	512	2,353
7/04	1,169	882	0	0	0	2,051
7/05	1,169	899	0	0	0	2,068
7/06	1,014	1,477	0	0	0	2,491
7/07	207	2,979	0	0	0	3,186
7/08	351	4,596	0	0	0	4,947
7/09	449	5,599	0	0	0	6,048
7/10	520	6,254	0	0	0	6,774
7/11	990	7,143	0	0	0	8,133
7/12	679	7,990	0	0	78	8,747
7/13	523	8,192	0	0	0	8,715
7/14	400	6,008	0	0	1,865	8,273
7/15	319	5,341	0	0	1,833	7,493
7/16	904	3,887	0	0	1,406	6,197
7/17	254	3,952	0	0	986	5,192
7/18	93	4,253	0	0	940	5,286
7/19	134	4,410	0	0	710	5,254
7/20	63	5,048	0	0	714	5,825
7/21	0	4,329	0	0	1,297	5,626
7/22	0	6,271	0	0	0	6,271
7/23	0	6,334	0	0	0	6,334
7/24	0	6,156	0	0	0	6,156
7/25	0	6,525	0	0	0	6,525
7/26	73	5,671	0	0	0	5,744
7/27	51	4,759	0	0	162	4,972
7/28	0	4,021	0	0	5	4,026
7/29	0	3,419	0	0	6	3,425
7/30	0	3,012	0	0	66	3,078
7/31	0	2,478	0	0	52	2,530
8/01	0	2,516	0	0	4	2,520
8/02	41	2,761	0	0	6	2,808
8/03	39	2,900	0	0	7	2,946
8/04	0	3,031	0	0	560	3,591
8/05	0	3,999	0	0	72	4,071
8/06	0	4,142	0	0	160	4,302

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Date	Chinook	S chum	F chum	Coho	Other	Total
8/07	0	4,159	0	0	150	4,309
8/08	0	4,195	0	0	71	4,266
8/09	0	0	4,260	0	298	4,558
8/10	0	0	3,582	0	147	3,729
8/11	0	0	3,370	0	125	3,495
8/12	0	0	2,966	0	159	3,125
8/13	0	0	3,015	0	61	3,076
8/14	0	0	2,479	0	100	2,579
8/15	0	0	2,228	0	54	2,282
8/16	0	0	1,911	0	42	1,953
8/17	0	0	1,715	0	34	1,749
8/18	0	0	1,444	30	0	1,474
8/19	0	0	1,294	187	0	1,481
8/20	0	0	1,142	170	0	1,312
8/21	0	0	1,236	130	39	1,405
8/22	0	0	1,483	154	47	1,684
8/23	0	0	1,626	268	100	1,994
8/24	0	0	2,159	225	56	2,440
8/25	0	0	2,174	391	25	2,590
8/26	0	0	1,799	450	532	2,781
8/27	0	0	1,807	486	638	2,931
8/28	0	0	1,498	969	596	3,063
8/29	0	0	1,961	763	96	2,820
8/30	0	0	1,445	1,121	92	2,658
8/31	0	0	1,089	1,443	152	2,684
9/01	0	0	1,626	821	71	2,518
9/02	0	0	2,080	958	49	3,087
9/03	0	0	2,670	654	387	3,711
9/04	0	0	2,667	621	292	3,580
9/05	0	0	2,801	1,094	138	4,033
9/06	0	0	3,816	1,215	281	5,312
9/07	0	0	5,064	1,249	609	6,922
9/08	0	0	8,189	1,719	126	10,034
9/09	0	0	13,789	1,782	519	16,090
9/10	0	0	17,072	3,289	1,017	21,378
9/11	0	0	16,752	2,963	2,316	22,031
9/12	0	0	13,559	2,791	2,364	18,714
9/13	0	0	12,913	2,756	2,785	18,454
9/14	0	0	9,805	3,727	1,210	14,742
9/15	0	0	9,066	4,967	636	14,669
9/16	0	0	7,828	2,440	2,356	12,624
9/17	0	0	6,512	2,059	2,364	10,935

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Date	Chinook	S chum	F chum	Coho	Other	Total
9/18	0	0	6,425	2,843	808	10,076
9/19	0	0	6,199	2,646	825	9,670
9/20	0	0	6,378	2,739	318	9,435
9/21	0	0	4,972	2,928	239	8,139
9/22	0	0	4,912	1,781	1,389	8,082
9/23	0	0	3,859	2,817	66	6,742
9/24	0	0	3,673	1,379	574	5,626
9/25	0	0	2,317	2,035	685	5,037
Total	15,502	165,526	222,627	61,060	39,564	504,279
SE	1,703	2,292	3,193	2,465	3,303	5,945
CV	0.110	0.014	0.014	0.040	0.083	0.012
Lower 90% CI	12,701	161,756	217,375	57,005	34,131	494,500
Upper 90% CI	18,303	169,296	227,879	65,115	44,997	514,058

Note: The left and right bank sonars were operated June 26–September 25, but the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

APPENDIX G: DAILY CUMULATIVE FISH PASSAGE PROPORTIONS AND TIMING BY SPECIES

Appendix G1.–Daily cumulative fish passage proportions and timing by species at the Tanana River sonar project, 2013.

Date	Chinook	S chum	F chum	Coho	Other	Total
7/16	**0.291**	0.077	0.001	0.000	0.004	0.006
7/17	**0.604**	0.159	0.002	0.001	0.014	0.014
7/18	**0.796**	**0.254**	0.003	0.001	0.027	0.023
7/19	0.881	0.380	0.003	0.001	0.028	0.028
7/20	0.983	**0.503**	0.004	0.001	0.046	0.040
7/21	0.983	0.503	0.005	0.001	0.068	0.047
7/22	0.983	0.503	0.007	0.001	0.097	0.057
7/23	0.983	0.503	0.009	0.002	0.133	0.069
7/24	0.983	0.503	0.010	0.002	0.164	0.079
7/25	0.983	0.503	0.011	0.002	0.188	0.088
7/26	0.983	0.503	0.013	0.002	0.214	0.096
7/27	0.983	0.503	0.014	0.002	0.239	0.105
7/28	0.983	0.503	0.015	0.002	**0.255**	0.110
7/29	0.983	0.503	0.015	0.002	0.268	0.114
7/30	0.983	0.503	0.016	0.002	0.279	0.118
7/31	0.983	0.606	0.016	0.002	0.292	0.126
8/01	0.983	0.681	0.017	0.002	0.305	0.133
8/02	1.000	**0.757**	0.017	0.002	0.314	0.139
8/03	1.000	0.826	0.018	0.002	0.322	0.144
8/04	1.000	0.888	0.018	0.002	0.329	0.149
8/05	1.000	0.944	0.019	0.002	0.337	0.153
8/06	1.000	1.000	0.019	0.002	0.345	0.158
8/07	1.000	1.000	0.019	0.002	0.350	0.160
8/08	1.000	1.000	0.020	0.002	0.356	0.162
8/09	1.000	1.000	0.020	0.002	0.361	0.163
8/10	1.000	1.000	0.020	0.002	0.365	0.165
8/11	1.000	1.000	0.020	0.002	0.369	0.166
8/12	1.000	1.000	0.021	0.002	0.373	0.168
8/13	1.000	1.000	0.021	0.002	0.378	0.170
8/14	1.000	1.000	0.021	0.002	0.383	0.171
8/15	1.000	1.000	0.025	0.003	0.389	0.175
8/16	1.000	1.000	0.029	0.003	0.394	0.179
8/17	1.000	1.000	0.032	0.003	0.399	0.182
8/18	1.000	1.000	0.036	0.003	0.403	0.185
8/19	1.000	1.000	0.040	0.003	0.406	0.189
8/20	1.000	1.000	0.043	0.005	0.406	0.191
8/21	1.000	1.000	0.047	0.005	0.406	0.193
8/22	1.000	1.000	0.050	0.006	0.406	0.195
8/23	1.000	1.000	0.052	0.007	0.406	0.196
8/24	1.000	1.000	0.055	0.010	0.406	0.198
8/25	1.000	1.000	0.057	0.010	0.406	0.199
8/26	1.000	1.000	0.060	0.013	0.406	0.201
8/27	1.000	1.000	0.063	0.017	0.406	0.203

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Date	Chinook	S chum	F chum	Coho	Other	Total
8/28	1.000	1.000	0.072	0.024	0.409	0.210
8/29	1.000	1.000	0.082	0.036	0.412	0.217
8/30	1.000	1.000	0.093	0.053	0.416	0.226
8/31	1.000	1.000	0.110	0.067	0.420	0.238
9/01	1.000	1.000	0.135	0.081	0.427	0.256
9/02	1.000	1.000	0.170	0.102	0.435	0.280
9/03	1.000	1.000	0.211	0.125	0.441	0.307
9/04	1.000	1.000	**0.251**	0.148	0.446	0.333
9/05	1.000	1.000	0.290	0.172	0.458	0.361
9/06	1.000	1.000	0.326	0.219	0.479	0.392
9/07	1.000	1.000	0.361	**0.264**	**0.521**	0.428
9/08	1.000	1.000	0.397	0.293	0.598	0.474
9/09	1.000	1.000	0.448	0.330	0.658	0.525
9/10	1.000	1.000	**0.510**	0.348	0.722	0.581
9/11	1.000	1.000	0.572	0.402	**0.777**	0.638
9/12	1.000	1.000	0.638	0.457	0.810	0.691
9/13	1.000	1.000	0.709	**0.512**	0.842	0.745
9/14	1.000	1.000	**0.772**	0.586	0.875	0.797
9/15	1.000	1.000	0.834	0.666	0.898	0.846
9/16	1.000	1.000	0.901	0.735	0.909	0.894
9/17	1.000	1.000	0.972	**0.817**	0.923	0.945
9/18	1.000	1.000	0.986	0.883	0.930	0.961
9/19	1.000	1.000	0.993	0.925	0.938	0.971
9/20	1.000	1.000	0.999	0.959	0.948	0.980
9/21	1.000	1.000	0.999	0.978	0.964	0.987
9/22	1.000	1.000	1.000	0.991	0.983	0.994
9/23	1.000	1.000	1.000	1.000	1.000	1.000

Note: The 25th, 50th, and 75th percentiles are in bold. The left bank sonar operated July 13–September 23, but not July 19 or August 20–August 27. The right bank sonar operated July 14–September 17, but not July 21–July 30 or August 7–14. The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11 and consistently September 12–23, and set gillnets fished September 10–23. The Chinook and summer chum salmon estimates are from the right bank only, and estimates for all species are considered incomplete. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

Appendix G2.–Daily cumulative fish passage proportions and timing by species at the Tanana River sonar project, 2014.

Date	Chinook	S chum	F chum	Coho	Other	Total
6/26	0.048	0.003	0.000	0.000	0.009	0.002
6/27	0.111	0.008	0.000	0.000	0.021	0.006
6/28	0.160	0.012	0.000	0.000	0.035	0.009
6/29	0.200	0.016	0.000	0.000	0.035	0.011
6/30	0.200	0.016	0.000	0.000	0.038	0.011
7/01	**0.263**	0.023	0.000	0.000	0.044	0.015
7/02	0.334	0.030	0.000	0.000	0.053	0.019
7/03	0.391	0.036	0.000	0.000	0.066	0.023
7/04	0.466	0.041	0.000	0.000	0.066	0.026
7/05	**0.542**	0.047	0.000	0.000	0.066	0.030
7/06	0.607	0.056	0.000	0.000	0.066	0.034
7/07	0.621	0.074	0.000	0.000	0.066	0.041
7/08	0.643	0.101	0.000	0.000	0.066	0.052
7/09	0.672	0.135	0.000	0.000	0.066	0.065
7/10	0.706	0.173	0.000	0.000	0.066	0.079
7/11	**0.770**	0.216	0.000	0.000	0.066	0.096
7/12	0.813	**0.264**	0.000	0.000	0.068	0.115
7/13	0.847	0.314	0.000	0.000	0.068	0.134
7/14	0.873	0.350	0.000	0.000	0.115	0.150
7/15	0.893	0.382	0.000	0.000	0.161	0.165
7/16	0.952	0.406	0.000	0.000	0.197	0.176
7/17	0.968	0.430	0.000	0.000	0.222	0.186
7/18	0.974	0.455	0.000	0.000	0.245	0.197
7/19	0.983	0.482	0.000	0.000	**0.263**	0.208
7/20	0.987	**0.513**	0.000	0.000	0.281	0.220
7/21	0.987	0.539	0.000	0.000	0.314	0.231
7/22	0.987	0.577	0.000	0.000	0.314	0.245
7/23	0.987	0.615	0.000	0.000	0.314	0.259
7/24	0.987	0.652	0.000	0.000	0.314	0.273
7/25	0.987	0.692	0.000	0.000	0.314	0.288
7/26	0.992	0.726	0.000	0.000	0.314	0.300
7/27	0.995	**0.755**	0.000	0.000	0.318	0.311
7/28	0.995	0.779	0.000	0.000	0.318	0.320
7/29	0.995	0.799	0.000	0.000	0.318	0.328
7/30	0.995	0.818	0.000	0.000	0.320	0.335
7/31	0.995	0.833	0.000	0.000	0.321	0.340
8/01	0.995	0.848	0.000	0.000	0.322	0.346
8/02	0.997	0.865	0.000	0.000	0.322	0.352
8/03	1.000	0.882	0.000	0.000	0.322	0.359
8/04	1.000	0.900	0.000	0.000	0.336	0.366
8/05	1.000	0.925	0.000	0.000	0.338	0.375
8/06	1.000	0.950	0.000	0.000	0.342	0.385
8/07	1.000	0.975	0.000	0.000	0.346	0.394

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Date	Chinook	S chum	F chum	Coho	Other	Total
8/08	1.000	1.000	0.000	0.000	0.347	0.404
8/09	1.000	1.000	0.019	0.000	0.355	0.414
8/10	1.000	1.000	0.035	0.000	0.359	0.422
8/11	1.000	1.000	0.050	0.000	0.362	0.429
8/12	1.000	1.000	0.064	0.000	0.366	0.436
8/13	1.000	1.000	0.077	0.000	0.367	0.443
8/14	1.000	1.000	0.088	0.000	0.370	0.449
8/15	1.000	1.000	0.098	0.000	0.371	0.454
8/16	1.000	1.000	0.107	0.000	0.372	0.458
8/17	1.000	1.000	0.115	0.000	0.373	0.462
8/18	1.000	1.000	0.121	0.000	0.373	0.465
8/19	1.000	1.000	0.127	0.004	0.373	0.468
8/20	1.000	1.000	0.132	0.006	0.373	0.471
8/21	1.000	1.000	0.138	0.008	0.374	0.474
8/22	1.000	1.000	0.144	0.011	0.375	0.478
8/23	1.000	1.000	0.152	0.015	0.378	0.482
8/24	1.000	1.000	0.161	0.019	0.379	0.487
8/25	1.000	1.000	0.171	0.025	0.380	0.492
8/26	1.000	1.000	0.179	0.033	0.393	0.497
8/27	1.000	1.000	0.187	0.041	0.410	0.503
8/28	1.000	1.000	0.194	0.057	0.425	0.508
8/29	1.000	1.000	0.203	0.069	0.427	0.513
8/30	1.000	1.000	0.209	0.088	0.429	0.518
8/31	1.000	1.000	0.214	0.111	0.433	0.522
9/01	1.000	1.000	0.221	0.125	0.435	0.527
9/02	1.000	1.000	0.231	0.140	0.436	0.532
9/03	1.000	1.000	0.243	0.151	0.446	0.540
9/04	1.000	1.000	**0.255**	0.161	0.453	0.547
9/05	1.000	1.000	0.267	0.179	0.457	0.554
9/06	1.000	1.000	0.285	0.199	0.464	0.564
9/07	1.000	1.000	0.307	0.219	0.479	0.578
9/08	1.000	1.000	0.344	0.248	0.483	0.598
9/09	1.000	1.000	0.406	**0.277**	0.496	0.632
9/10	1.000	1.000	0.483	0.331	**0.521**	0.675
9/11	1.000	1.000	**0.558**	0.379	0.580	0.718
9/12	1.000	1.000	0.619	0.425	0.640	0.755
9/13	1.000	1.000	0.677	0.470	0.710	0.790
9/14	1.000	1.000	0.721	**0.531**	0.741	0.817
9/15	1.000	1.000	**0.762**	0.612	**0.757**	0.844
9/16	1.000	1.000	0.797	0.652	0.816	0.867
9/17	1.000	1.000	0.826	0.686	0.876	0.886
9/18	1.000	1.000	0.855	0.733	0.896	0.905
9/19	1.000	1.000	0.883	**0.776**	0.917	0.922
9/20	1.000	1.000	0.911	0.821	0.925	0.940

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Date	Chinook	S chum	F chum	Coho	Other	Total
9/21	1.000	1.000	0.934	0.869	0.931	0.955
9/22	1.000	1.000	0.956	0.898	0.967	0.969
9/23	1.000	1.000	0.973	0.944	0.968	0.981
9/24	1.000	1.000	0.990	0.967	0.983	0.992
9/25	1.000	1.000	1.000	1.000	1.000	1.000

Note: The 25th, 50th, and 75th percentiles are in bold. The left and right bank sonars operated June 26–September 25, but the left bank sonar did not operate June 29 and the right bank sonar did not operate June 30. The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Estimates are considered nearly complete. The other species included broad whitefish, humpback whitefish, least cisco, sheefish, burbot, northern pike, and longnose sucker.

APPENDIX H: NUMBER OF FISH CAUGHT BY ZONE AND MONTH

Appendix H1.–Number of fish caught by zone and month in the Tanana River sonar project test fishery, 2013.

Zone	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
1	July	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	August	0	0	0	0	0	0	0	0	0	0	0
	September	0	0	357	33	0	2	0	0	0	0	392
	Total	0	0	357	33	0	2	0	0	0	0	392
2	July	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	August	0	0	0	0	0	0	0	0	0	0	0
	September	0	0	20	14	20	20	0	17	0	7	98
	Total	0	0	20	14	20	20	0	17	0	7	98
3	July	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	August	0	0	1	0	0	0	0	0	0	0	1
	September	0	0	91	62	13	9	0	0	16	0	191
	Total	0	0	92	62	13	9	0	0	16	0	192
4	July	36	675	0	0	5	6	0	0	0	0	722
	August	1	267	640	68	8	7	3	0	2	0	996
	September	0	0	4,151	523	18	19	4	0	0	0	4,715
	Total	37	942	4,791	591	31	32	7	0	2	0	6,433

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). The fish wheel operated July 16–September 23; drift gillnets fished sporadically August 5–September 11, and consistently September 12–September 23; and set gillnets fished September 10–September 23. Much of the Chinook and summer chum salmon runs were missed in the right bank test fishery, and were missed entirely in the left bank test fishery. Some of the late fall chum and coho salmon runs were missed as well. The whitefish catch included humpback whitefish and broad whitefish.

Appendix H2.–Number of fish caught by zone and month in the Tanana River sonar project test fishery, 2014.

Zone	Month	Chinook	S chum	F chum	Coho	Whitefish	Cisco	Sheefish	Burbot	Sucker	Pike	Total
1	June	5	2	0	0	0	0	0	0	0	0	7
	July	11	242	0	0	2	0	1	0	0	0	256
	August	0	114	140	12	5	9	0	1	7	0	288
	September	0	0	563	174	5	6	1	0	1	0	750
	Total	16	358	703	186	12	15	2	1	8	0	1,301
2	June	0	0	0	0	0	1	0	0	0	1	2
	July	0	23	0	0	0	8	1	0	6	3	41
	August	0	15	40	18	4	2	1	0	3	0	83
	September	0	0	423	321	8	23	3	7	24	0	809
	Total	0	38	463	339	12	34	5	7	33	4	935
3	June	12	1	0	0	0	0	0	0	0	0	13
	July	10	229	0	0	1	0	0	1	0	0	241
	August	0	1	24	7	0	0	0	0	0	0	32
	September	0	0	69	60	1	1	0	0	0	0	131
	Total	22	231	93	67	2	1	0	1	0	0	417
4	June	0	0	0	0	0	0	0	0	0	0	0
	July	34	873	0	0	2	2	4	0	0	0	915
	August	1	200	1,026	235	43	35	5	2	1	0	1,548
	September	0	0	9,892	1,933	153	106	5	4	1	0	12,094
	Total	35	1,073	10,918	2,168	198	143	14	6	2	0	14,557

Note: Zone 1 = right bank nearshore (drift gillnets); Zone 2 = left bank nearshore (drift and set gillnets); Zone 3 = left bank offshore (drift gillnets); Zone 4 = right bank nearshore (fish wheel). The fish wheel operated July 11–September 23, but not August 4; drift gillnets fished June 26–September 25; and set gillnets fished June 26–July 27. Some of the early Chinook and summer chum salmon runs, and late fall chum and coho salmon runs were missed. The whitefish catch included humpback whitefish and broad whitefish.